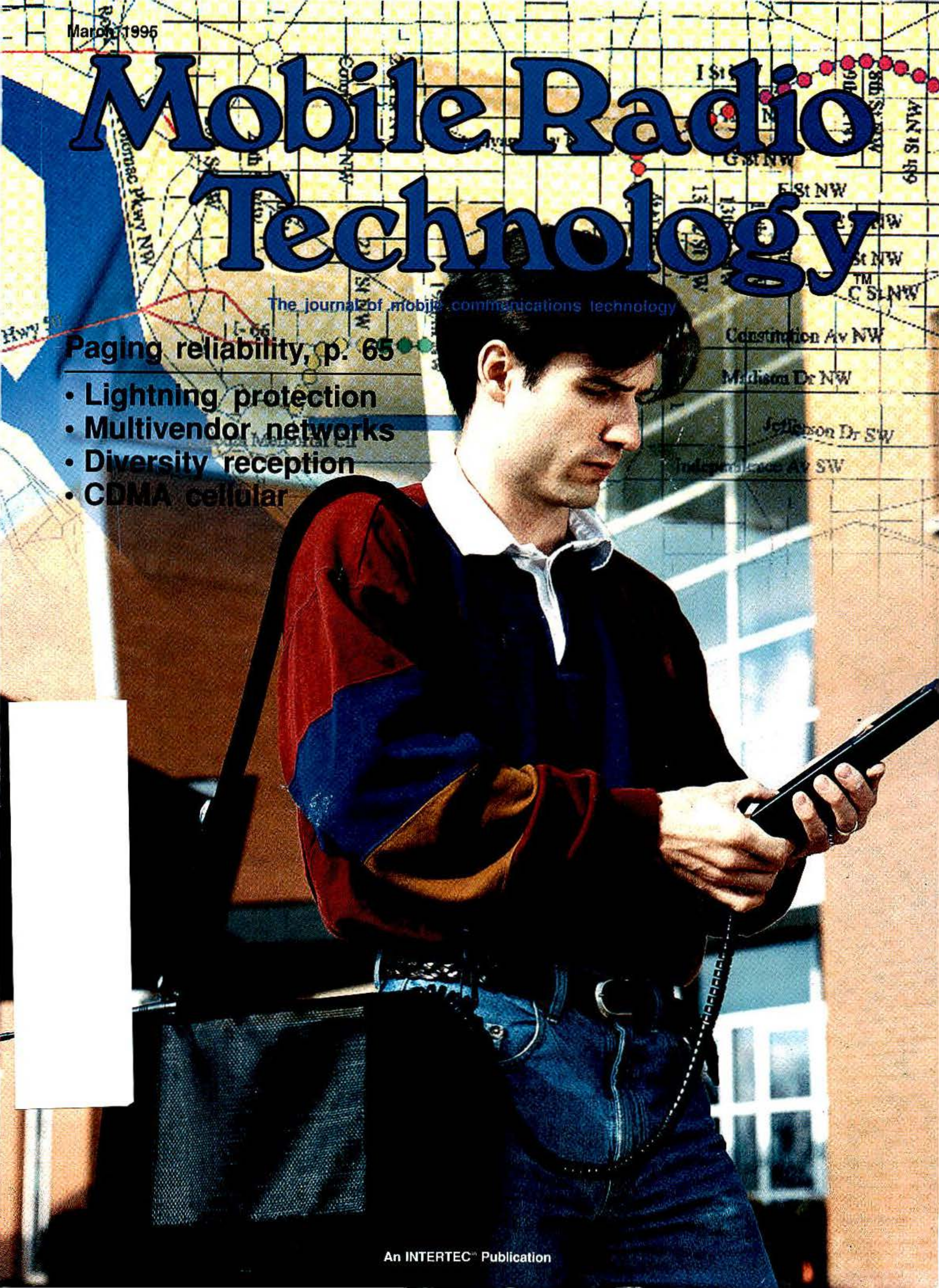
March 1995

Mobile Radio Technology™

The journal of mobile communications technology

Paging reliability, p. 65

- Lightning protection
- Multivendor networks
- Diversity reception
- CDMA cellular



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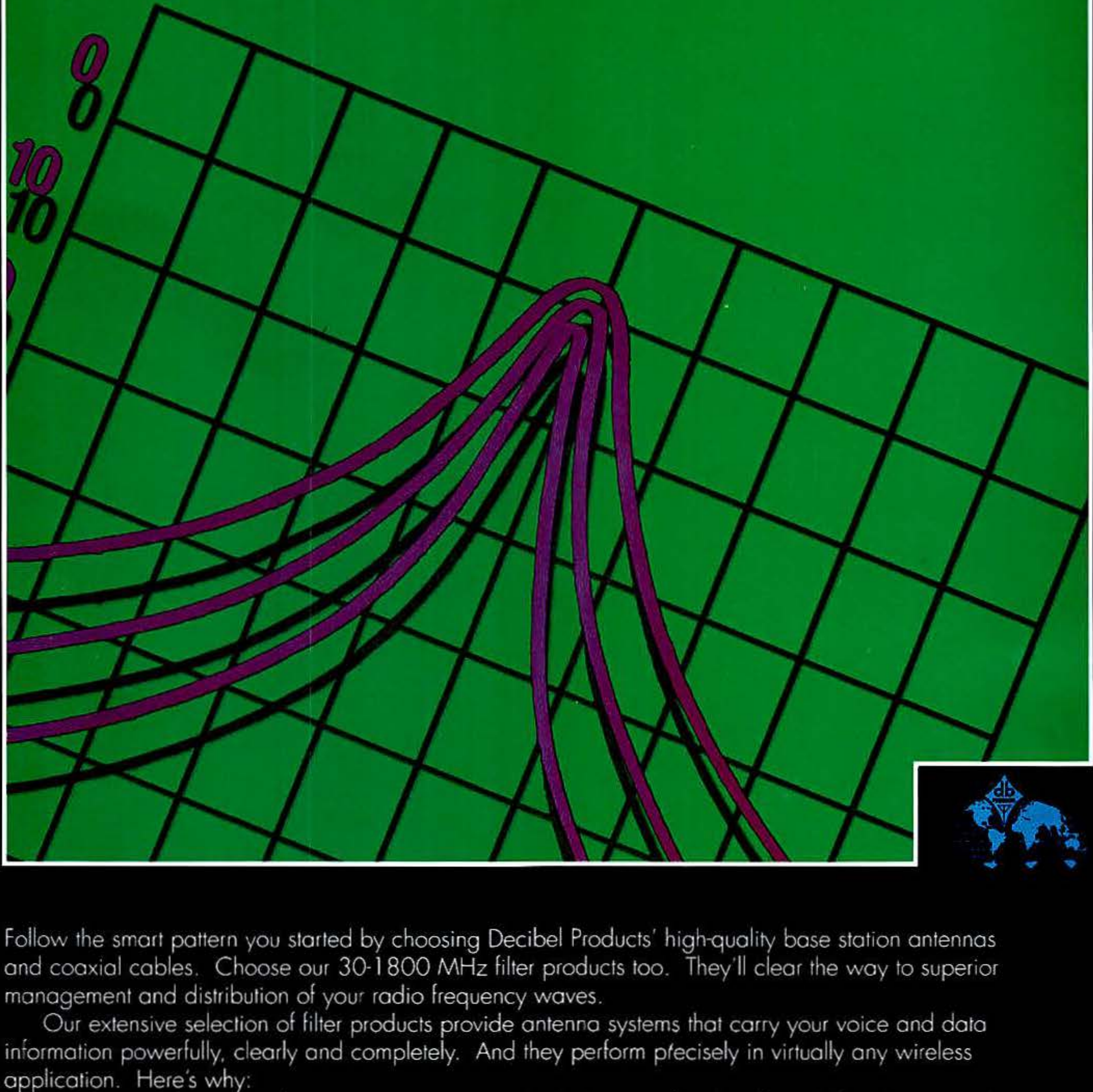

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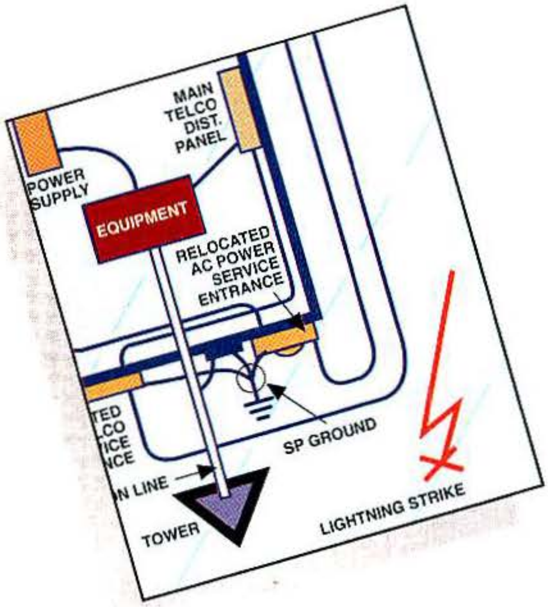

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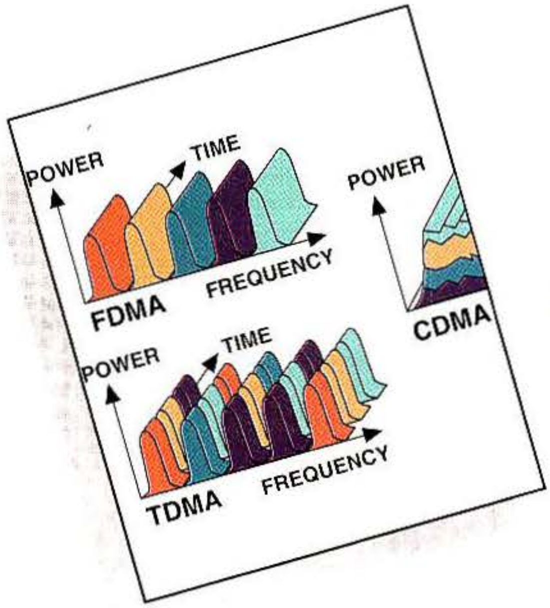

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features

On the cover: A technician uses a portable wireless measurement tool to check paging system performance. *Photo courtesy of Grayson Electronics, Forest, VA.*

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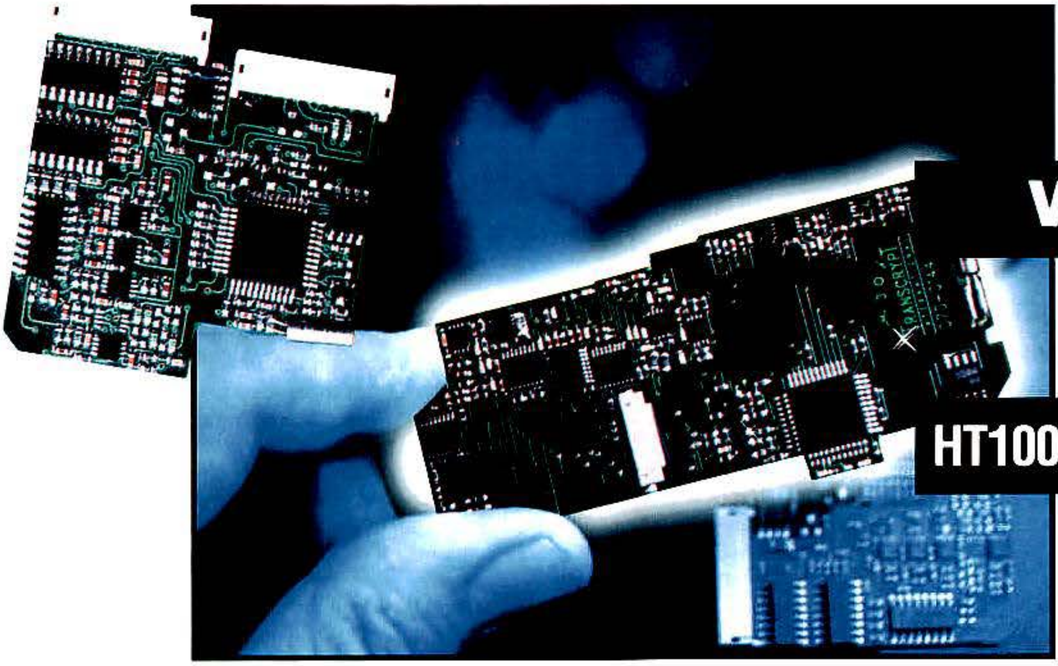

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FCC vs. James Kay: Enforcement or vendetta?

On July 17, James A. Kay Jr., a Los Angeles radio system operator, will have an opportunity to appear at an FCC hearing (postponed from March 27) involving 164 land mobile radio licenses. The commission designated the hearing in connection with an Order to Show Cause and the possible revocation of the licenses and the possible issuance of a forfeiture order (a fine) after Kay sued three of its employees, W. Riley Hollingsworth, Terry L. Fishel and Anne Marie Wypijewski, on a complaint that they violated his civil rights.

Kay's complaint is specific. It details how the FCC employees may have denied him due process of law, may have attempted to conduct an unreasonable search, may have taken his property unlawfully and may have violated his right of privacy.

The FCC's order is, on the other hand, vague. Part of it is based on what the commission says are complaints from others that Kay may have violated construction rules for some of his licensed stations, but it does not say which stations and when. Another part of the order alleges that Kay falsely reported the number of mobiles his stations serve (referred to as loading), but again without saying which stations and when. Defending against such allegations requires knowing times and places. Can you imagine trying to defend yourself in a driver's license revocation hearing, for example, if the motor vehicle bureau said it wanted to revoke your license for speeding, but did not say when, where or how fast?

Another part of the order alleges that Kay did not respond to requests for written statements of fact required by law. So far as we know, Kay responded to all such requests, but the problem seems to be that someone in the FCC does not like his answers. He did not include customer lists that later could be distributed to his competitors, for example. Customer lists are valuable to competitors, and once delivered to the FCC, they can be placed in the hands of the public by various processes. In fact, the FCC has demonstrated its capacity to distribute confidential information about Kay to his competitors on its own initiative.

Another part of the order alleges that Kay "may" willfully cause interference to radio systems. Not that he *does*, but that he *may*, and again without saying where or when.

The administrative law judge assigned to the hearing, Richard Sippel, had ordered the FCC and Kay to submit status reports on Jan. 24, including a list of any witnesses they expected to call. Kay submitted a list; the FCC said it was not ready to name witnesses. It named no witnesses who would testify as to his character qualifications to be a commission licensee, and no witnesses who would substantiate the allegations in the order to show cause. This seems incredible. Does the FCC *have* any witnesses to the alleged misuse of commission processes, loading violations and malicious interference?

In previous cases, the FCC has demonstrated the ability to write an order to show cause that describes "who did what, and when and where it happened." If it has sufficient evidence to support its allegations against Kay, why wouldn't it write an order to show cause that demonstrates the strength of its case? Why wouldn't it comply with the judge's order to submit a list of witnesses?

We don't know whether Kay has violated any FCC rules or federal laws in the conduct of his business and the operation of his radio systems. We do know that he is entitled to fair treatment. This order to show cause is so vague and makes so many allegations without reference to times and places that it apparently is being used in an attempt to damage Kay's business, rather than to remedy rule violations. Kay has been standing up to what he sees as abuses of authority by FCC employees, and it looks as though the commission is seeking retribution.

—Don Bishop

Calendar

March

13-14—AMTEX, the American Mobile Telecommunications Association's Marketing and Technology Conference and Exposition, The Buttes, Tempe, AZ. Contact: 202-331-7773.

16-17—Government Land Mobile Communications Conference, sponsored by TMSA Conferences, Rosslyn Westpark Hotel, Arlington, VA. Contact: Steven Silver, 310-534-4871.

20-23—Supercomm, sponsored by USTA and TIA, Anaheim Convention Center, Anaheim, CA. Contact: 202-326-7300.

April

3-5—Energy Telecommunications and Electrical Association, George R. Brown Convention Center, Houston. Contact: 214-235-0655.

25-27—International Wireless Communications Expo/Spring, Las Vegas Sands Convention Center, Las Vegas. Contact: 800-828-0420.

May

17-19—Mobile Communications Conference, sponsored by the Personal Communications Industry Association (PCIA), Hotel del Coronado, San Diego. Contact: Nancy Palleschi, 800-759-0300.

31-June 2—Radiocomm, Toronto Metropolitan Convention Center, Toronto. Contact: 613-233-4888.

July

26-28—Vehicular Technology Conference, sponsored by IEEE Vehicular Technology Society, Hyatt Regency Chicago O'Hare, Chicago. Contact: Keith Paglusch, chairman, 312-399-2378.

31-Aug. 4—Utilities Telecommunications Council, Hyatt Regency and Convention Center, Minneapolis. Contact: 202-872-0030.

August

13-18—Association of Public-Safety Communications Officials—International National Conference, Detroit. Contact: 800-949-2726.

September

20-23—Personal Communications Showcase, sponsored by the Personal Communications Industry Association (PCIA), Orange County Convention Center, Orlando, FL. Contact: 800-326-8638.

October

18-20—International Wireless Communications Expo/Fall, Tampa Convention Center, Tampa, FL. Contact: 800-828-0420.

26—ERA Communications Trade Fair, Ala Moana Hotel, Honolulu. Contact: 310-287-1218.

29-Nov. 1—Wireless Apps, sponsored by the Cellular Telecommunications Industry Association, The Mirage Hotel, Las Vegas. Contact: 202-785-0081.

November

7-9—WirelessWorld Conference and Exposition, sponsored by *Cellular Business* and *Mobile Radio Technology* magazines, Moscone Convention Center, San Francisco. Contact: Chris Lotesto, 800-458-0479.

8-12—Communications Marketing Conference, sponsored by the Communications Marketing Association, Albuquerque, NM. Contact: Bernie Brownson, 303-371-8182.

17—Radio Club of America, Communications Symposium, 86th Anniversary Dinner and Awards Presentation, New York Athletic Club, New York. Contact: Ron Formella, 201-652-6811.

1996

March

23-25—Wireless '96, sponsored by the Cellular Telecommunications Industry Association, Dallas. Contact: 202-785-0081.

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The journal of mobile communications technology

CORRESPONDENCE: Editorial and advertising correspondence should be addressed to P.O. Box 12901, Overland Park, KS 66282-2901, 913-341-1300, fax: 913-967-1904.

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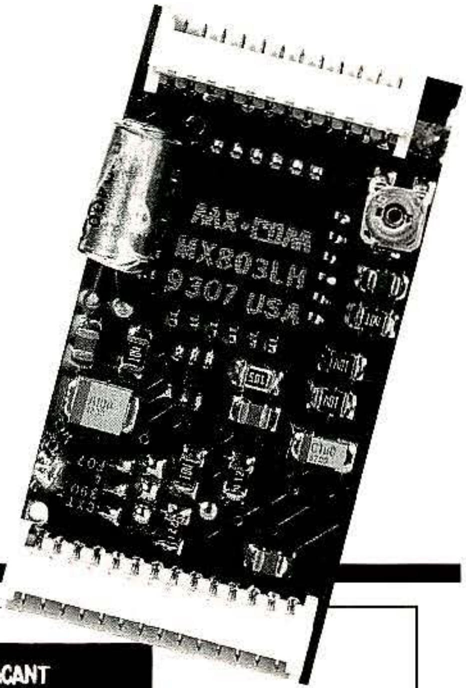

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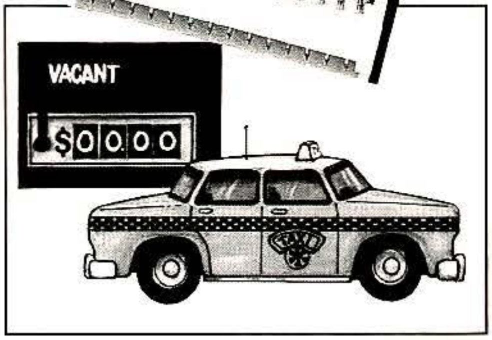

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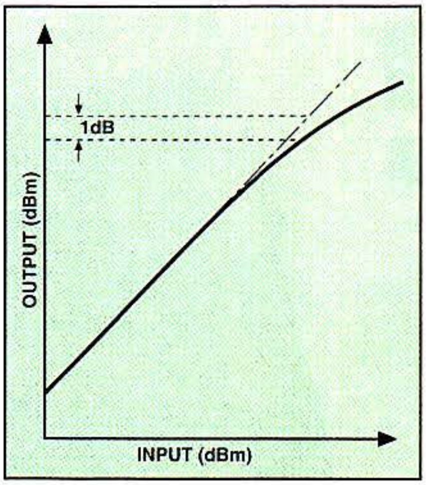


Figure 1. The 1dB compression point of an amplifier.

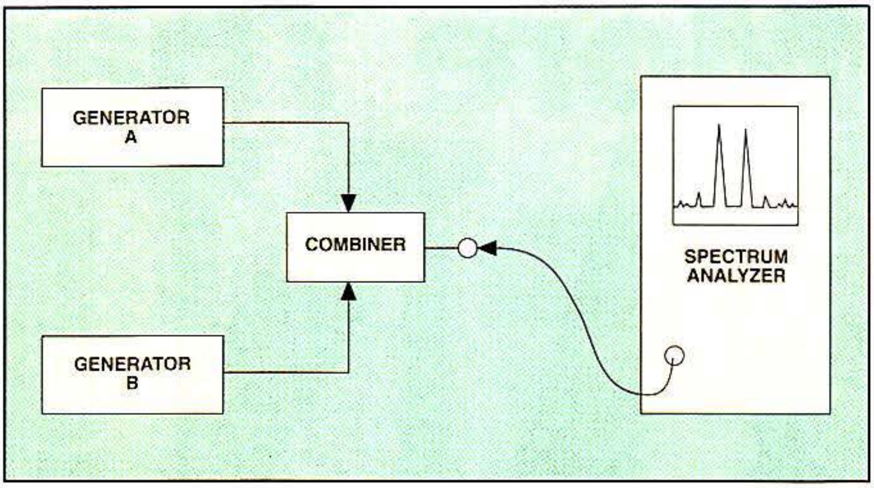


Figure 2. A simplified test setup for determining a spectrum analyzer's dynamic range.

Intermodulation distortion

By Harold Kinley, C.E.T.

An overdriven or overloaded amplifier distorts the signal it is intended to amplify. *Intermodulation distortion* (IMD) describes one type of distortion that results.

Figure 1 above left shows the result of overdriving an amplifier. With low input levels, the amplifier's output signal gives a true reproduction of the input signal. However, when the input signal reaches a certain level, *compression* begins. Note the point where the output signal is compressed by 1dB, which means that the output level increases 1dB less than the input level. For example, when a 3dB increase in the input level produces a 2dB increase in the output level, as illustrated in Figure 1, 1dB compression has occurred. Specifications for many amplifiers and other devices include the 1dB compression point.

When compression begins, IMD results. The IMD begins at a low level and rises rapidly as the input level increases beyond the point of compression.

Test setup

Figure 2 above right shows a simplified setup for measuring IMD produced in the spectrum analyzer. Essentially a sophisticated superheterodyne receiver, a spectrum analyzer can have the same problems as any other superheterodyne receiver. In this test setup, generators A and B generate two continuous wave (CW) tones at RF frequencies. A special combiner (not a simple "T" connector) combines their output and connects it to the spectrum analyzer input. When the input levels to the spectrum analyzer begin to overdrive or overload the analyzer, IMD occurs. Third-order IMD signals at frequencies of 2A – B and 2B – A form. (2A – B is two times the frequency of tone A minus the frequency of tone B.)

Highly accurate tests require a more complex test setup than depicted in Figure 2. For example, a low-pass filter should be inserted between each generator and the combiner to suppress harmonics, and a high degree of isolation must be provided to prevent interaction between the two generators. The combiner provides some

(continued on page 68)

Kinley, a certified electronics technician, is regional communications manager, South Carolina Forestry Commission, Spartanburg, SC. He is the author of *Standard Radio Communications Manual: With Instrumentation and Testing Techniques*, Prentice-Hall, 1985. He is a member of the Radio Club of America.

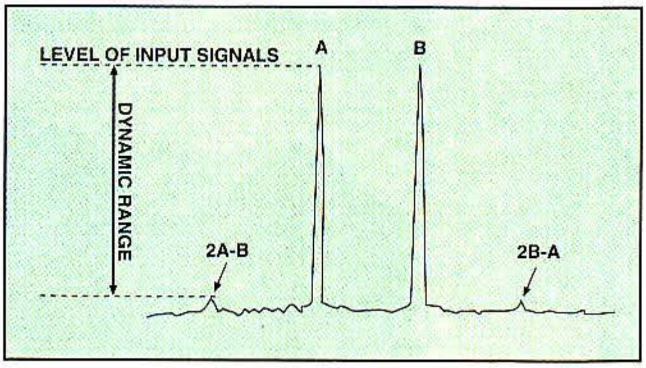


Figure 3. A spectrum analyzer's dynamic range equals the difference of the reference tones (A or B) and the level of the IM signals as the IM signals rise just above the spectrum analyzer's noise floor.

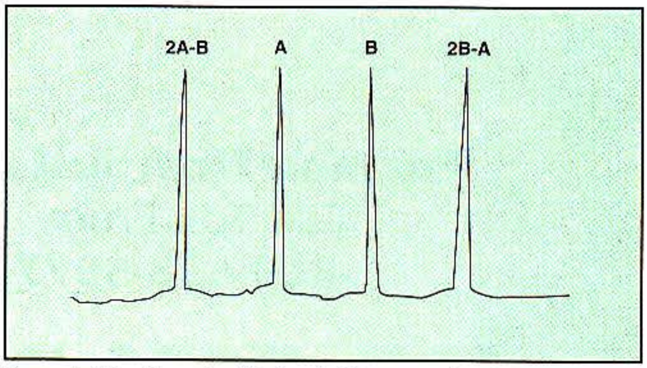


Figure 4. At the theoretical third-order intercept point, the level of the IM signals equals the level of the reference tones. Severe amplifier compression would prevent this condition from occurring in a practical amplifier.

Single-point grounding for communications sites

Single-point grounding is the most critical element of a three-part process involving effective bonding and grounding, transient voltage surge suppression and structural lightning protection.

By Bruce A. Kaiser

"Single-point grounding" is a current buzzword in protecting communications sites from the ravages of lightning and general ground transients.

Kaiser is president of Lightning Master, Clearwater, FL.

What is single-point grounding? Actually, the term, as used here, is a misnomer. Single-point ground electrical potential referencing has nothing to do with the grounding system itself or with the provision of only a single path from a particular piece of equipment back to the internal grounding provisions. The grounding system is determined by the soil conditions and other factors at a specific site. As a practical matter, it is impossible to provide modern equipment with one, and only one, ground return path to the internal grounding provisions.

Single-point ground electrical potential referencing means connecting all site equipment to the grounding system at a single point, or, more precisely, bonding all communications site equipment to the grounding system in such a way that all of the equipment samples ground potential at one, and only one,

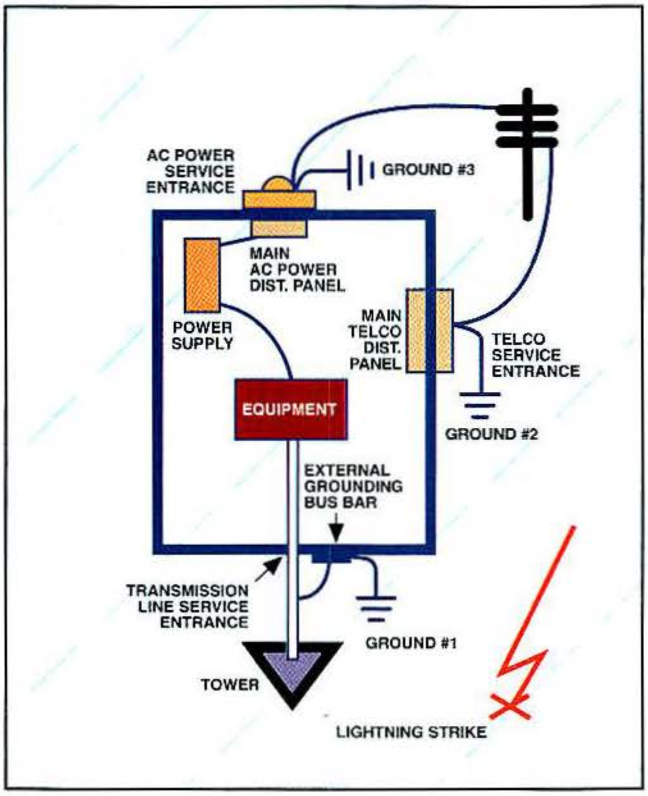


Figure 1. At many sites, the ac power service entrance is at one end of the equipment shelter, the telco service entrance is at one side, and the transmission line service entrance is at the end opposite the ac power entrance. Each service is grounded where it enters the shelter. When lightning strikes near the site, the ground potential changes across the site due to secondary effect.

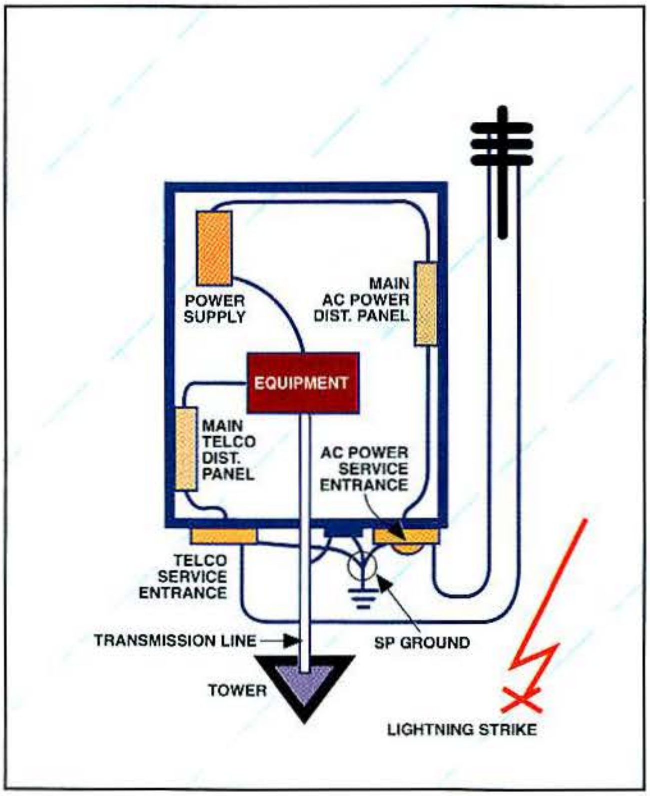
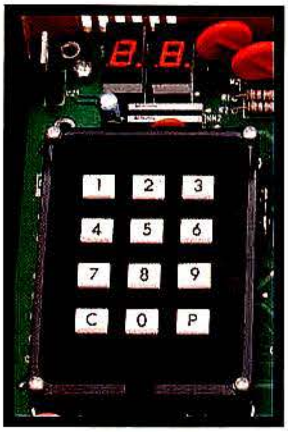
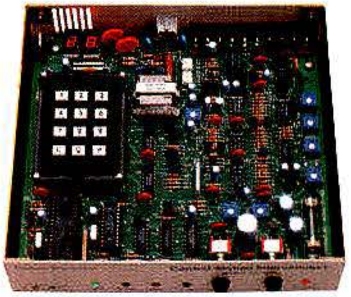


Figure 2. Make the transmission line potential the site reference potential by placing a large copper bus bar on the equipment shelter's outside wall below the transmission line service entrance. Install a transmission line grounding kit and bond it to the bus bar. Run a large lead from the bus bar to the site grounding system to place the RF side of the site equipment at the potential of the bus bar.

WHAT TO LOOK FOR IN A PATCH...





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point (hence, single-point).

'Potential' damage

A change in electrical potential in and of itself does not damage equipment. It is a *difference* in electrical potential across or within a piece of equipment that causes damage. If one radio is connected to both the coaxial cables from the tower and to a power supply, and there is a difference in electrical potential between those two services, that difference in potential equalizes within the radio, causing damage or accelerated wear. The same risk applies to two pieces of equipment communicating with one another through data lines. If there is a difference in electrical potential between the two pieces of equipment, that potential equalizes through the data lines within one or both pieces of equipment. (Communications site equipment, in this case, refers only to electrical or electronic equipment. Communications site equipment does not include door frames, air conditioning ducting or the tower.)

Single-point ground definition

Envision an imaginary plane at or just below the floor of the site. All of the site equipment is appropriately bonded together above this plane, and an appropriate grounding system is established below this plane. Those two systems are bonded together at one, and only one, hole through that plane. Therefore, all equipment within the site is at the ground potential of that single point. The single-point ground is defined as the point at which the unified ground passes through this plane.

Several ground potentials are involved in a typical communications site. The first set of ground potentials is associated with ac power, telephone lines and RF transmission lines to the site. The second set is associated with the various electrical and electronic equipment chassis. There are other sources, too, but the following information covers these two.

Changes in ground potential across a site may be caused by a variety of factors, but the most dramatic and familiar is lightning. During a thunderstorm, the charge at the base of the storm cloud induces a shadow of opposite charge on the surface of the earth beneath it. As the storm cloud blows along through the atmosphere, this ground charge, or more accurately, earth surface charge, is dragged along the surface of the earth beneath it.

Cloud-to-ground lightning results when the difference in electrical potential between the storm cloud charge and the ground charge exceeds the dielectric of the intervening air. That air breaks down in a series of steps, and the lightning strike occurs. When lightning strikes a particular point on earth, the ground charge at that point is vacated relative to the surrounding ground charge. The surrounding charge rushes to the point of the strike.

Ground charge distribution

Looking at the distribution of ground charge immediately after a strike, it is apparent that the ground charge potential will change with distance from the strike. A point close to the strike will be at a quite different potential compared to another point at a greater distance from the strike. If a ground rod is driven at each of these points and the electrical potential between the two rods could be measured during a lightning strike, the measurement would indicate a dramatic and almost instantaneous difference in potential between the ground rods. If a power supply were grounded

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to one of the rods and a radio powered by it were grounded to the other, during a strike the radio would see a difference in electrical potential between its power input and chassis. This difference in electrical potential will equalize within the radio.

At many sites, the ac power service entrance is at one end of the equipment shelter, the telco service entrance is at one side, and the transmission line service entrance is at the end opposite the ac power entrance. (See Figure 1 on page 10.) Each service is grounded where it enters the shelter. When lightning strikes near the site, the ground potential changes across the site due to secondary effect. The propagation rate of the ground charge causes a difference in ground potential (dashed lines) at each service entrance ground. The equipment within the shelter therefore sees a difference in potential between the RF input at the potential of ground No. 1, the power input at the potential of ground No. 3, and the telco input at the potential of ground No. 2. That difference in potential is equalized across and within the equipment, causing wear or damage.

Transmission line ground

With respect to the ground potential of the services to the site, the most difficult service potential to control is the transmission line from the tower. This potential is difficult to control in part because the tower usually is several yards away from the shelter, and the tower's potential is constantly changing.

The transmission line ground potential can be limited relative to the rest of the site, or the transmission line potential can be made the reference potential for the remainder of the site equipment. Based on experience with Florida cell sites, the second solution is easier to implement—and actually more effective.

Grounding configuration

The transmission line potential can be made the site reference potential (single

When lightning strikes near the site, the ground potential changes across the site due to secondary effect.

point) by placing a large copper bus bar on the equipment shelter's outside wall just below the transmission line service entrance. A grounding kit is installed on the transmission line (in addition to the grounding kits already installed at the top and bottom of the tower) and bonded to the bus bar. A large lead is run from the bus bar to the site grounding system. This configuration places the RF side of the site equipment at the potential of this bus bar. (See Figure 2 on page 10.)

Then we route the ac service to the site so it meets the equipment shelter just to one side of the transmission line service entrance. At the main disconnect, the ac neutral and ground are bonded together, and a ground lead extends from that box. This ground lead should be attached to either the transmission line service entrance bus bar or to the large ground lead from that bus bar above the point at which it attaches to the grounding system. This assures that the ac power side (and low

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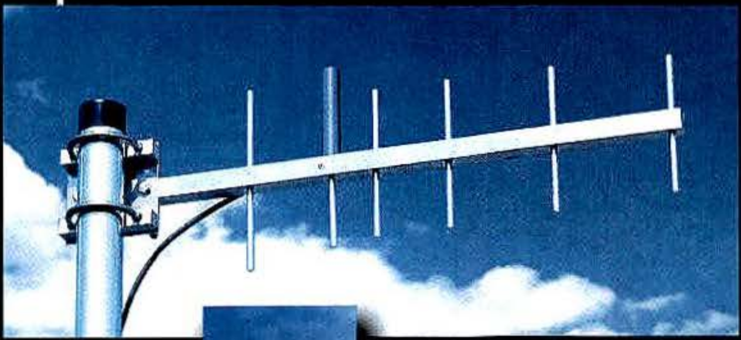

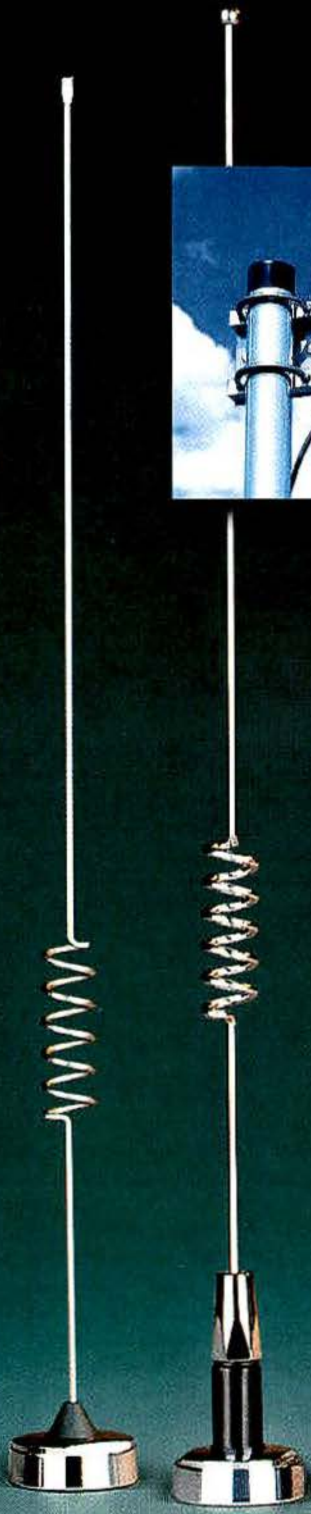

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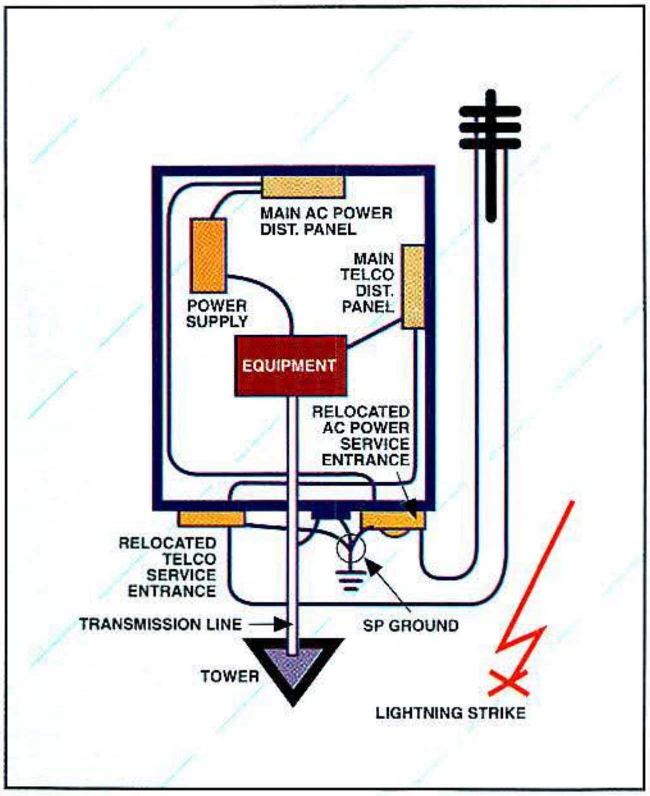

Figure 3. One of two things can be done about transmission line ground potential: It can be limited relative to the rest of the site, or the transmission line potential can be made the reference potential for the remainder of the site equipment. Based on experience with Florida cell sites, the second solution is easier to implement and actually more effective, as shown above.

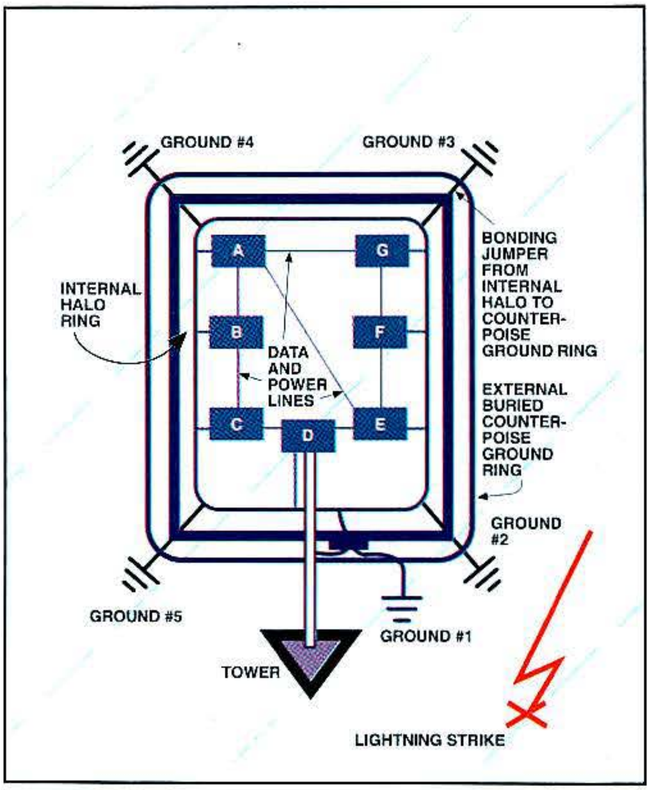

Figure 4. In many sites, an internal halo ground is installed at the shelter perimeter and bonded to ground at all four corners. Site equipment is bonded to the halo at a convenient location, so any given piece of equipment samples the closest grounding point. During a nearby lightning strike, the ground potential at one corner of the site could differ vastly from the ground potential at any other corner.

voltage power side) ground of the site equipment will be at the same potential as the transmission line bus bar and therefore at the same potential as the RF side of the equipment. (See Figure 3 above left.)

Then the telco service is routed to the site so it meets the equipment shelter on the opposite side of the transmission line service entrance. The ground lead extending from the telco service box is attached either to the transmission service entrance bus bar or to the large ground lead from that bus bar above the point where it attaches to the grounding system. This configuration assures that the telco side of the site equipment is at the same potential as the transmission line bus bar and therefore at the same potential as the RF and power sides of the equipment.

With this arrangement, any difference in ground potential among services to the site is equalized at the single point, and the site equipment samples all ground potentials at one, and only one, point: the single-point ground. A nearby lightning strike would produce the same step potential across the site, but because all site equipment is attached to services sampling the ground potential at only one point (and there is no other ground reference potential), the equipment sees no current flow across or within it to equalize electrical potential.

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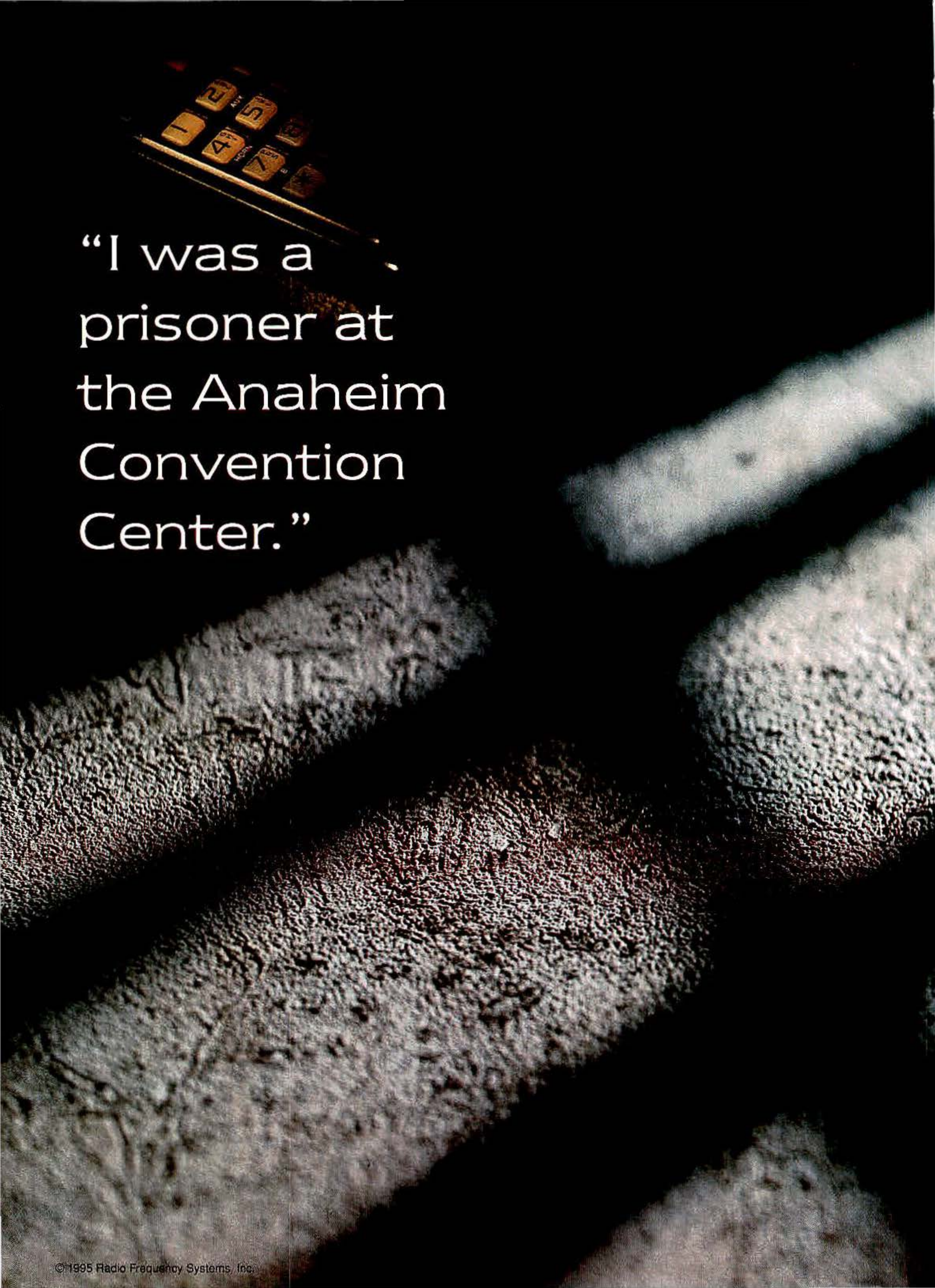
"I was a prisoner at the Anaheim Convention Center."

to design into a new site. But what about an existing site? The internal distribution routing of ac power and telco lines is already established, and it is difficult and expensive to change it. The answer is to leave the existing internal distribution routing intact and just move the service entrances. With the ac power, move the main disconnect to a location near the transmission line service entrance and ground it to the single point. Then run a "primary jumper" internally back to the existing distribution panel. This way, none of the distribution routing needs to be changed.

The same technique should be employed with the telco service. Move the demarcation or service entrance to the transmission line service entrance and establish its ground at the single point.

As expensive as it may be to move service entrances, it is less expensive than replacing damaged equipment or equipment that wears out prematurely. At least it is not necessary to reroute the internal distribution of the ac power and telco lines within the shelter.

Chassis grounding

The next area of grounding concern is chassis grounding. In many sites, particularly older ones, an internal halo ground was installed around the perimeter of the shelter near the ceiling or floor and bonded to ground at all four corners of the shelter. (See Figure 4 on page 16.) Site equipment then was bonded to the halo at the closest or most convenient location, so that piece of equipment sampled ground potential at the closest grounding point. During a nearby lightning strike, the ground potential at one corner of the site could be vastly different from the ground potential at any other corner. The chassis potential of each piece of equipment will be closest to the potential of the ground at the nearest corner of the building. The chassis potential of component A, as shown in the figure, will be close to the potential of ground No. 4. The chassis potential of component C will be close to the potential of ground No. 5, and the chassis potential of component E will be close to the potential of ground No. 2. Because many pieces of equipment communicate with one another through data lines, and all of them share the power source, electrical potential differences equalize within and through the site equipment.

During a nearby lightning strike, the ground potential at one corner of the site could be vastly different from the ground potential at any other corner.

Interior bus bar

The solution is to bond the chassis of each piece of equipment to ground at the same point. (See Figure 5 on page 22.) The easiest method is to install a copper bus bar inside the shelter on the opposite side of the same wall as the external transmission line bus bar. Each piece of site equipment is bonded to the internal bus bar, preferably with a bonding wire run from

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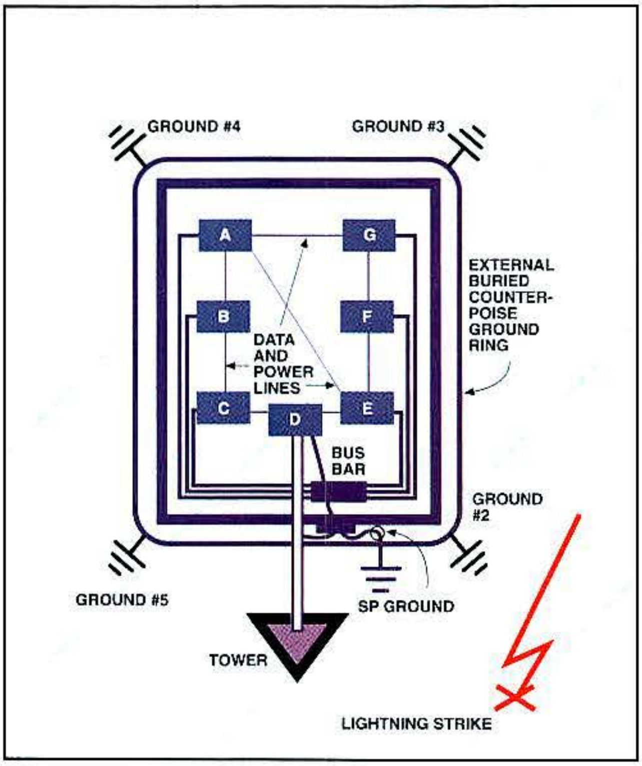


Figure 5. The solution to equalize electrical potential differences within and through the site equipment is to bond the chassis of each piece of equipment to ground at the same point. The easiest method is to install a copper bus bar inside the shelter on the opposite side of the same wall as the external transmission line bus bar and bond each piece of site equipment to the internal bus bar.

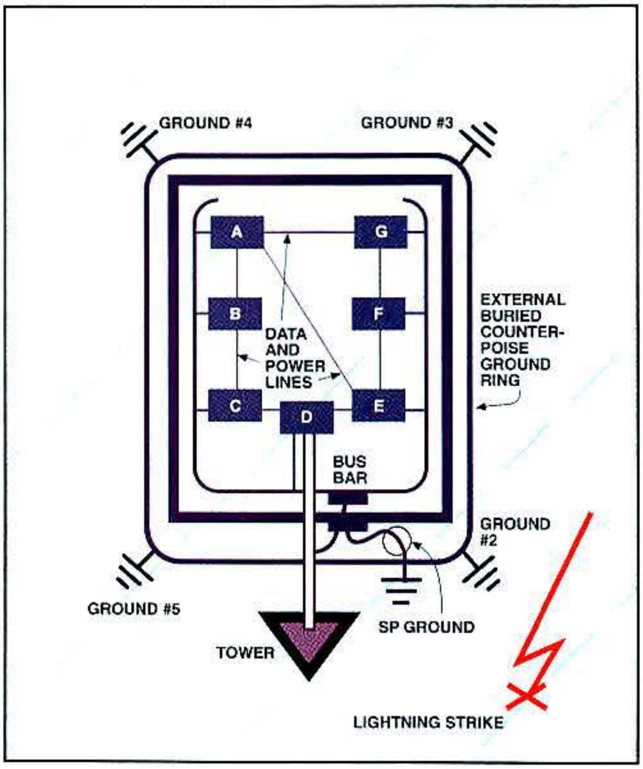


Figure 6. What about existing sites with internal halos grounded at multiple points to the external buried counterpoise? Ground the internal bus to the external bus ground lead. Cut the internal halo at the end of the building away from the transmission line service entrance. Cut each wire grounding the internal halo to the external buried counterpoise and remove them from the walls.

each chassis directly to the bus bar. The internal bus bar is bonded through the wall to the external bus bar. Ideally, equipment ground leads should be arranged across two internal bus bars according to how they produce or absorb surges, and whether they require non-isolated or isolated signal ground references. Whatever the case, all equipment should be chassis-grounded to one potential.

A nearby lightning strike now would produce the same step potential across the site, but because all site equipment chassis sample ground potential at only one point, and there is no other ground reference potential, the equipment sees no current flow across or within it to equalize electrical potential.

Buried counterpoise

The real purpose of the external buried counterpoise around the shelter is to protect people and the site from the adverse effects of step potential across the site during a nearby lightning strike; therefore, the counterpoise is important and should be part of any site grounding scheme. Even so, its purpose is not to provide a convenient "bus" to which equipment grounds should be tied.

The single-point chassis ground is effective and easy to design into a new site. But what about existing sites with internal halos grounded at multiple points to the external buried counterpoise? Fortunately, many problems at an older site can be solved with a good pair of wire cutters. First, ground the internal bus to the ex-

ternal bus ground lead. Then cut the internal halo at the end of the building away from the transmission line service entrance, eliminating the large ground loop. Then cut all wires grounding the internal halo to the external buried counterpoise and remove them from the walls. This modification leaves each equipment chassis grounded only at the single-point bus bar. During this process, be certain not to leave any piece of equipment ungrounded inadvertently. (See Figure 6 on page 22.) One of the ironies in this case is that it is less expensive and uses less material to ground the site properly than to install a multiple-point ground.

Direct lightning strike

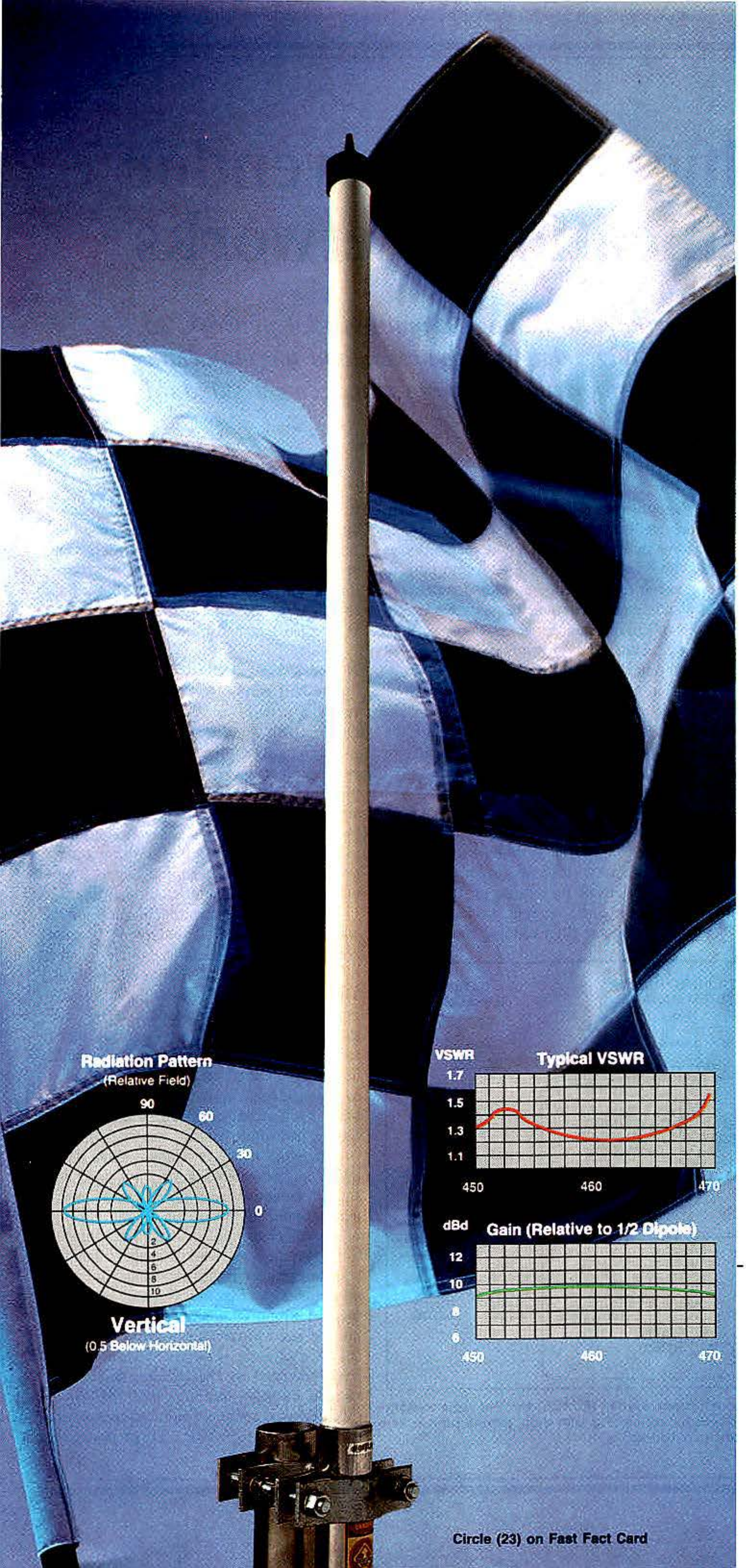
In all of the previous examples, a nearby lightning strike has been the cause of damage. A direct strike to the tower, equipment shelter or utility service pole on the site produces an even more impressive change in ground potential across the site. With a properly designed and installed single-point grounding system, the site should survive the ground potential change of even a direct strike. The electromagnetic pulse (EMP) and other effects of a close strike, and methods of mitigating their damage, are another story, but they are not covered in this article.

A few matters become apparent when considering single-point grounding of all services and equipment. The most obvious is that it is much easier to design a new site to this standard than it is to modify an existing site. Equipment shelters can be specified and ordered from the manufacturer with all service entrances at the same end of the shelter and adjacent to one another. Site layout can specify that all services be routed to the same end of the shelter. By the way, if the site has water from a commercial service or from a well, the water pipe should enter the facility at the same location and should be bonded to the single point. If the shelter has a structural lightning protection system, one of its grounding points should be bonded to the single point.

Transient suppression

If single-point grounding manages to reduce all equipment chassis and service grounds to the same electrical potential, what about the "hot" or "line" sides of those services? Any excess difference in electrical potential between the line side and the unified ground still will cause equipment damage or accelerated wear. Single-point grounding does not and cannot resolve that issue; therefore, it is important to install transient voltage surge suppression (TVSS) equipment in a "staged protection" design, with the primary TVSS device at the service entrance, to prevent equipment damage caused by an excess difference in electrical potential between the ground and hot or line sides of the services.

Lightning protection is a three-part process involving effective bonding and grounding, transient voltage surge suppression and structural lightning protection. Without all three elements, site equipment is not protected. Single-point grounding is but one element; nevertheless, it is probably the most basic element and the most critical to design into a site. The single-point grounding concept is not empty theory. It has been field-tested in the most lightning-damage-prone areas of the country and has proven to be effective. Put this simple concept to work to reduce damage and equipment wear.



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Managing multiple-vendor communications networks

Sooner or later you may have to manage a multi-vendor network, so prepare yourself now by selecting vendors that understand the importance of network management and support the emerging management standards.

By Tim Dailey

As communications systems evolve into communications networks, service providers must reconsider their management strategy. In the past, communications systems often were provided by a single vendor with a single management system. More recently, customer demands for new features have fueled a trend toward multi-vendor communications networks that integrate a variety of diverse technologies.

For example, the enhanced digital access communications system (EDACS) trunked radio system manufactured by my employer forms a comprehensive communications network by connecting with data, private branch exchange (PBX), microwave radio, and T1 telephone networks, as shown in Figure 1 below. Attempting to manage this type of multi-vendor network with current technology usually leads to a room full of management stations, because each vendor provides unique management equipment and software. This configuration in turn forces the network administrator to master all of the diverse management tools and to manually correlate the information provided by each. Clearly, a new management strategy is needed.

Dailey is program manager, EDACS management systems, Ericsson Private Radio Systems, Lynchburg, VA.

Consolidation attempts

Early attempts to consolidate these diverse management systems included replacing them with home-grown equipment and software or presenting all the unique screens on one machine, such as a personal computer (PC) running multiple terminal emulators. The first approach is costly, difficult to maintain and beyond the resources of most service providers. The second approach saves some space by reducing the number of terminals, but it fails to integrate the management information in a consistent and useful way.

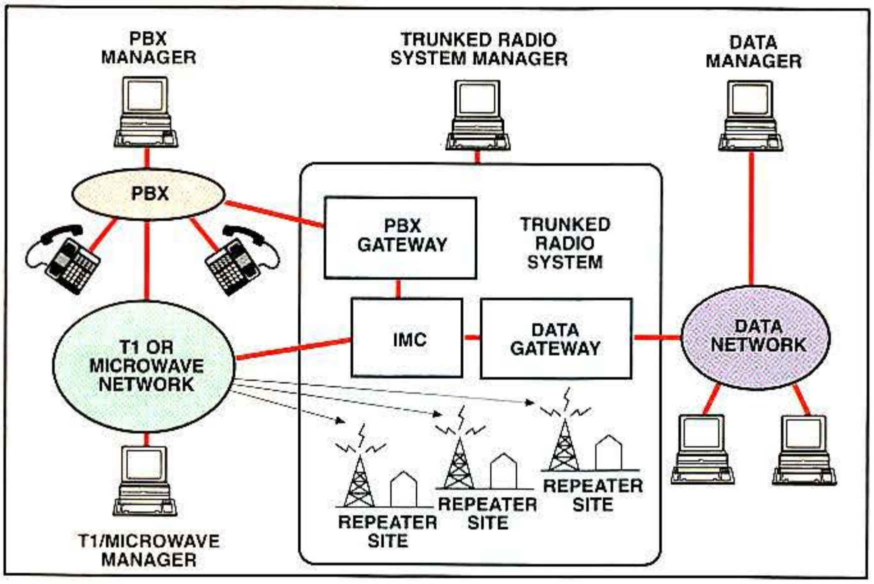

Figure 1. The enhanced digital access communications system (EDACS) trunked radio system forms a comprehensive communications network by connecting with data, private branch exchange (PBX), microwave radio, and T1 telephone networks.

Network manager

The best way to solve the problem is to create a network manager based on standards. Each vendor then could develop management applications based on the network manager standards. Multiple applications could be integrated simply on a single computer with a uniform user interface. A network manager would greatly improve network troubleshooting, repair and administration, resulting in lower operational costs and higher service quality.

Fortunately, the creation of such a network manager is well underway. Internet computer network users long have felt the need for a standard management tool. Their needs drove the development of several new management technologies. Although these technologies were developed for Internet management, they are general in nature and are currently being extended to manage telecommunications and many other technologies. These technologies enable true multi-vendor management.

A network manager contains three basic layers as shown in Figure 2 on page 28: *standard management protocols*, an *open management platform* and a large *library of management applications*. The foundation layer of a network manager includes standard protocols that exchange data with all network devices in the same way. This method simplifies integration by eliminating the need to develop a different protocol for each type of device. Two protocols have emerged as the leading standards: *simple network management protocol* (SNMP) and *common management information protocol* (CMIP). These protocols

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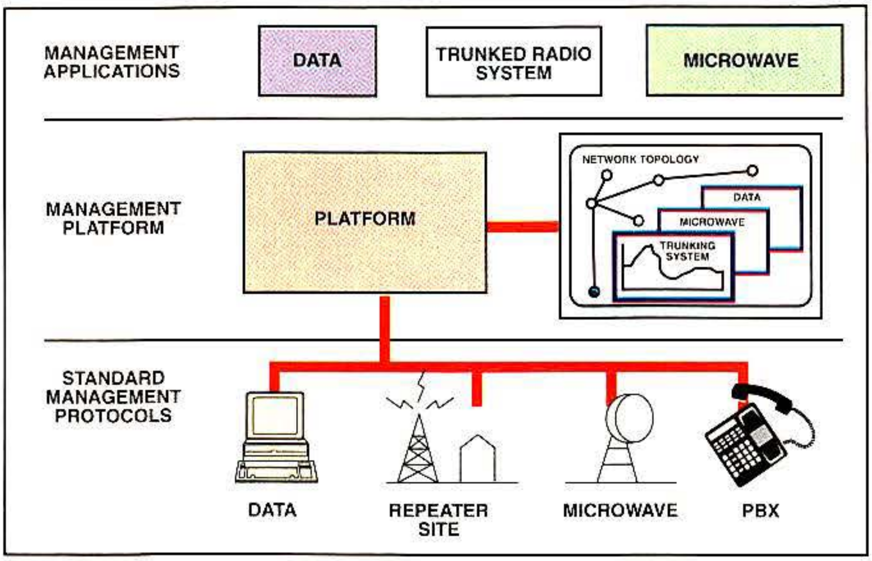

Figure 2. A network manager contains three basic layers: *standard management protocols*, an *open management platform* and a large *library of management applications.* The foundation layer of a network manager includes standard protocols that exchange data with all network devices in the same way.

allow a network manager to read and write management data stored in the *management information base* (MIB) of each device. The protocols also enable the network devices to notify the network manager of status changes or alarm conditions. Although one protocol would be ideal, two are better than thousands, and these two protocols are supported by most management platforms.

The intermediate layer contains the functions that glue the network manager components together. This layer contains the management platform that handles many of the low-level management functions and provides a framework to ensure that all applications have the same look and feel. The platform also combines information from all network elements, regardless of the vendor, in a synergistic way that enables the user to see the big picture and quickly identify problems.

> *The intermediate layer contains the functions that glue the network manager components together.*

Typical management platform

A simplified view of the typical management platform is shown in Figure 3 on page 30. The platform contains four major elements: *communications, common management functions, user interface* and *applications interface*. The communications section coordinates the data exchange with network elements. The platform should support SNMP, CMIP and provide hooks for nonstandard protocols as well. The common management functions block can be subdivided into network monitoring, alarm processing and performance monitoring. Network monitoring involves "pinging" each address on the network (i.e., sending a message and waiting for the response). This step allows the platform to detect new elements on the network and to verify that known elements are still on line. The alarm-processing function stores network alarms in a database for tracking and reporting, updates the display and triggers user-defined actions such as sounding an audible alarm or issuing a page to the appropriate person. Performance monitoring involves collecting MIB values from any combination of network elements and continuously graphing the results to summarize network performance. This function is extremely useful for detecting bottlenecks and degradation of service. The user interface ties all of the management information together through a graphical network map and integrated menu system. The application interface provides standard interfaces to the platform functions, allowing management applications to build on the foundation established by the platform. The application interface also ensures that applications from different vendors work in concert to pro-

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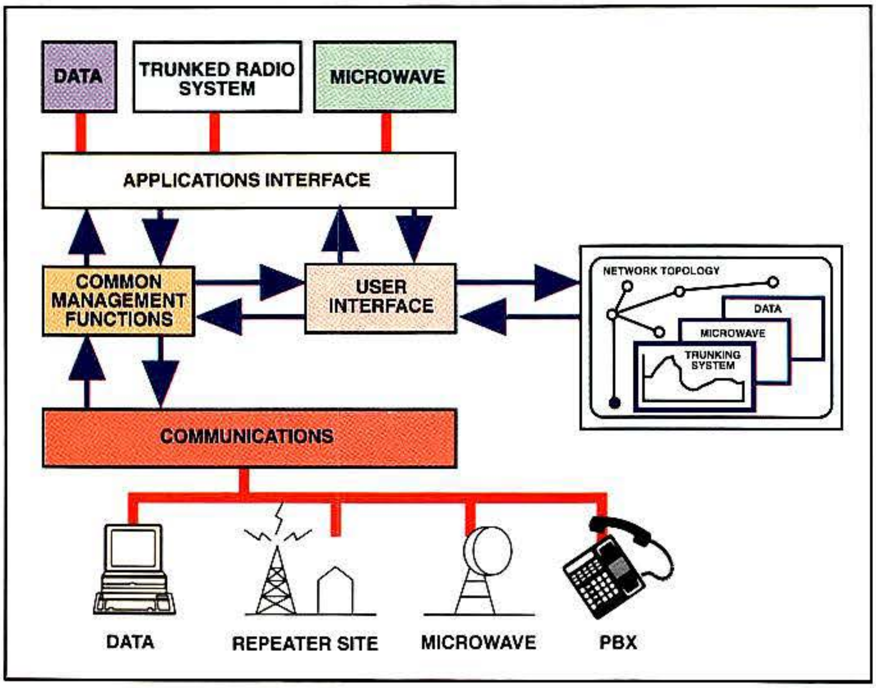


Figure 3. A simplified typical management platform contains four major elements: *communications, common management functions, user interface* and *applications interface*. The communications section coordinates the data exchange with network elements. The platform should support SNMP, CMIP and provide hooks for nonstandard protocols as well.

duce the appearance of a single product with a consistent interface and operation.

Management platforms are offered by several vendors including Hewlett-Packard, IBM, and Sun. Unfortunately, these management platforms are not interchangeable. Each has unique features and applications interfaces; nevertheless, several efforts are under way to simplify the sharing of applications and data between the different management platforms.

Management applications

The highest layer of the network manager contains management applications that flesh out the skeleton provided by the platform. These applications include product-specific management programs and integrated management-support tools. Though many management functions could be handled by a management platform alone, much time would be required to configure the platform for each network element. Product-specific applications eliminate the need for most user configuration by supplying icons, proper polling and alarm defaults, pre-configured performance graphs and reports as well as configuration and diagnostics

programs for each element. Integrated management-support tools automate general management functions such as trouble-ticketing, which monitors the progress of network repairs, and inventory management, which tracks the physical elements of the network.

Network topology

The three basic elements described above combine to form a complete network manager. Each vendor provides network elements that support SNMP or CMIP and a product-specific management application. These applications are installed on the management platform along with other management support tools. As an example, a hypothetical EDACS network manager is shown in Figure 4 to the right. The user interface is built around the network map. Each network element is represented by an individual icon located on a background geographical map. The icons are interconnected

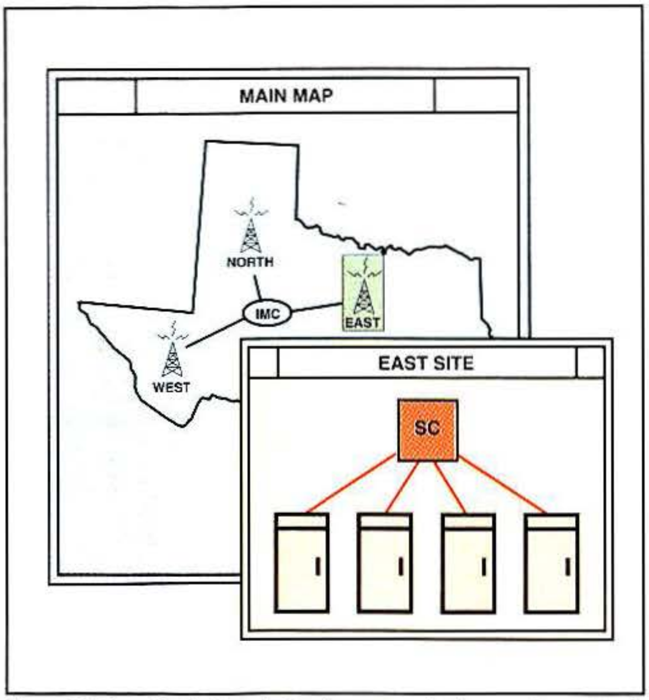
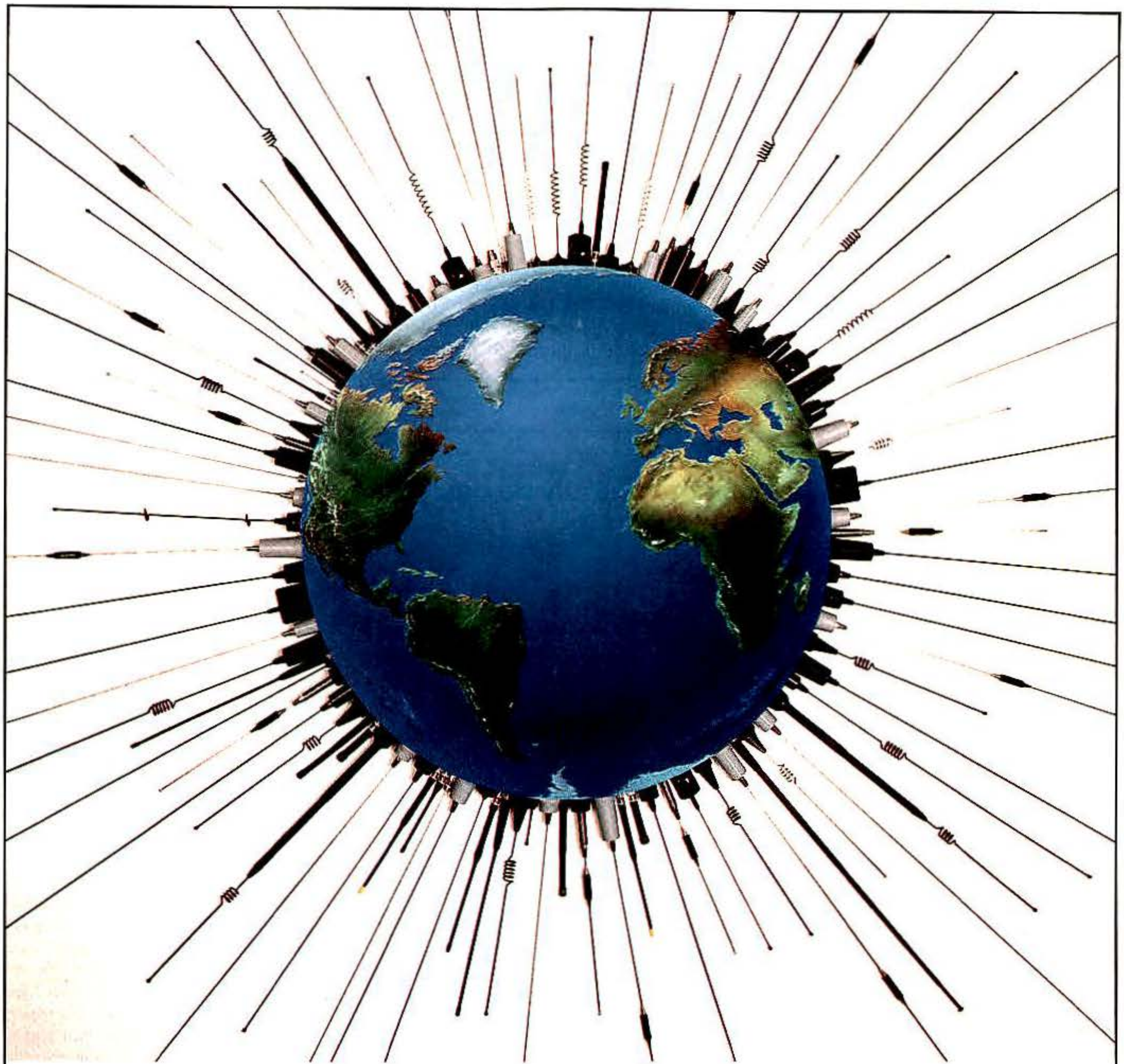


Figure 4. A hypothetical trunked radio communications system network manager includes a user interface built around the network map. Each network element is represented by a unique icon located on a background geographical map. The icons are interconnected with lines to represent the network topology.

with lines to represent the network topology. In this example, the highest network level consists of an *integrated multisite controller* (IMC) interconnecting several trunked systems in Texas. The network maps are layered to reduce clutter and confusion. Clicking on the icon with the mouse reveals the next layer of detail in a sub-map. In this case, clicking on the East site reveals the site controller computer and four RF channels. The layering continues until the lowest-level element is reached. At the lowest level, clicking on the icon brings up a menu of programs associated with the icon such as configuration, diagnostics or alarm status. The desired program is executed by clicking on the associated menu item. The user is free to bring up multiple windows with maps, configuration programs, performance plots or any other application sup-



ported by the network manager.

Initially, the network manager automatically discovers (auto-discovers) each network element, assigns the proper default polling and alarm parameters, and places the proper icon on the screen. The user must arrange the icons on the map and set up the hierarchy of submaps (i.e., network levels). The network manager immediately begins monitoring default MIB values in search of events. State changes in an element cause the associated icon to change color or blink. These visual changes propagate to the highest map level, allowing the user to monitor the highest level of interest and still detect low-level alarms. When an alarm occurs, the user simply clicks down through the sub-maps to find the offending device. Once the source of the alarm is located, the operator can run test and diagnostics programs to further determine the source of the problem.

Simplified management

The network map allows the user to see the big picture and quickly isolate network problems. The consistent user interface reduces the operator learning curve and speeds up daily activities. Performance graphs and reports identify potential problems before they become major faults, thereby improving the quality of service. All of these features simplify the management task and reduce the staff needed to manage the network.

If you are not presently managing a multi-vendor network, you probably will be in the near future. Therefore, it is important to consider network management in any communications purchase. Before buying, ask your vendor if their equipment supports SNMP or CMIP. Do they offer a management application on a standard platform such as Hewlett-Packard's OpenView? Is their management solution scalable, allowing you to start out small and grow as your network grows? Does their management solution interoperate with other management platforms and support a large library of management and non-management applications, allowing user customization?

The network map allows the user to see the big picture and quickly isolate network problems.

Managing a multi-vendor communications network will never be trivial, but it is becoming easier by the day. More and more vendors are supporting SNMP or CMIP and offering management applications on popular management platforms. Management platforms are beginning to interoperate and share applications while network management standards continue to evolve and expand. The future looks bright indeed, but there is no need to wait. Network management offers tremendous advantages today, including lower operational costs and better quality of service. Sooner or later you will have to manage a multi-vendor network, so prepare yourself now by selecting vendors that understand the importance of network management and support the emerging management standards.

Diversity reception controller helps radio system performance

Part 2—Using amplitude sensing, analog logic and output filtering along with low-cost integrated circuitry, an ideal selection diversity controller brings the advantages of diversity reception to commercial mobile communications.

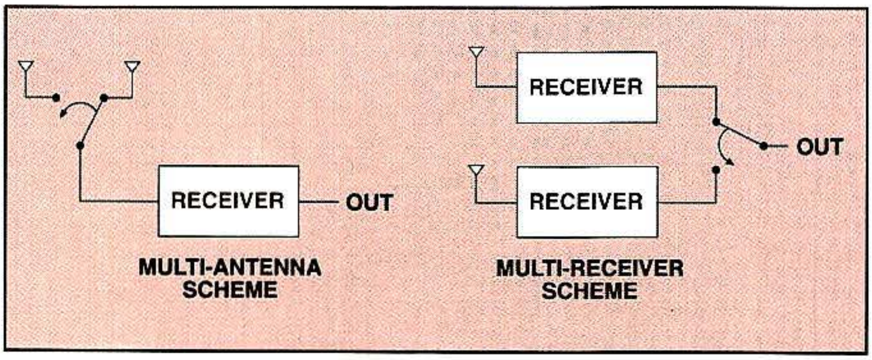


Figure 1. There are literally hundreds of variations on the concept of diversity reception. Most can be grouped into two main classifications of diversity reception systems, *multi-antenna systems* and *multi-receiver systems*, as shown above. Both of these schemes have proven largely unsuccessful, both technically and commercially, for a number of reasons.

By Shane Fitzgerald

Short-term (multipath) fading, as described in the first installment of this two-part article, is extremely destructive to high-speed data communications. What the ear would endure as one little pop or a hissing sound may destroy several hundred bits of information. An 800MHz mobile unit traveling at 15mph through a stationary environment will encounter 38 fades per second, and more if the environment includes moving objects such as trains, aircraft and automobiles. If these fades sink below the receiver's data recovery threshold, successful data reception becomes nearly impossible.

How can the integrity of data communications be protected in a fading environment? Two of the most popular and widely used methods are *forward error-correction* (FEC) and redundant transmissions.

With FEC, message reconstruction information is attached to each message prior to transmission. Should the message be received with errors, the reconstruction information is used to reconstruct the message. This method is complex. Message reconstruction taxes the receiver's processing power because it is computationally intensive, and it reduces system throughput significantly because an FEC code is added to each transmission.

With redundant transmissions, each message is transmitted multiple times and a majority voting process is used to decode the message. This simple scheme is less computationally intensive than FEC; but multiple transmissions of identical information are extremely inefficient and dramatically reduce system throughput.

FEC and redundant transmissions share two fundamental flaws in dealing with the destructive interference caused by multipath fading. The first flaw these systems exhibit is their fatalistic approach to the problem. Instead of trying to eliminate the source of the problem (short-term fading), these techniques try to recover from the damage the fading causes. The other flaw is that if the receiver remains stationary while in a deep fade, no amount of FEC or redundant transmissions will help; communication will not be possible.

Diversity reception, on the other hand, reduces destructive effects of multipath fading directly. Two closely spaced antennas receive signals that are considered to be uncorrelated; therefore, when one antenna experiences a fade, then the probability of the other antenna simultaneously experiencing a fade is extremely unlikely. By selecting between antennas or receivers quickly enough and in response to the fades, the damaging effects of short-term fading are dramatically reduced.

There are literally hundreds of variations on the concept of diversity reception. Most can be grouped into two main classifications of diversity reception systems, *multi-antenna systems* and *multi-receiver systems*, as shown in Figure 1 at the left. Both of these schemes have proven largely unsuccessful, both technically and commercially, for a number of reasons.

Multi-antenna diversity uses a single receiver with multiple antennas that are connected to it one at a time. When the receiver picks up an adequate signal from its current antenna, it maintains the connection. If the signal falls below a predetermined threshold, then the receiver switches to another antenna that *may* deliver a better signal.

Unfortunately, there is no guarantee that a better signal will be found when the receiver switches antennas. The signal may, in fact, be worse. Moreover, waiting until the threshold of reliable communication is reached before switching means that a problem already has been encountered, rather than avoided.

Multi-receiver diversity uses multiple receivers to supply recovered modulation. Special circuitry determines which

Fitzgerald is RF design engineer at ElectroCom Communications Systems, Santa Fe Springs, CA. ElectroCom manufactures the ideal selection diversity controller described in this two-part article.

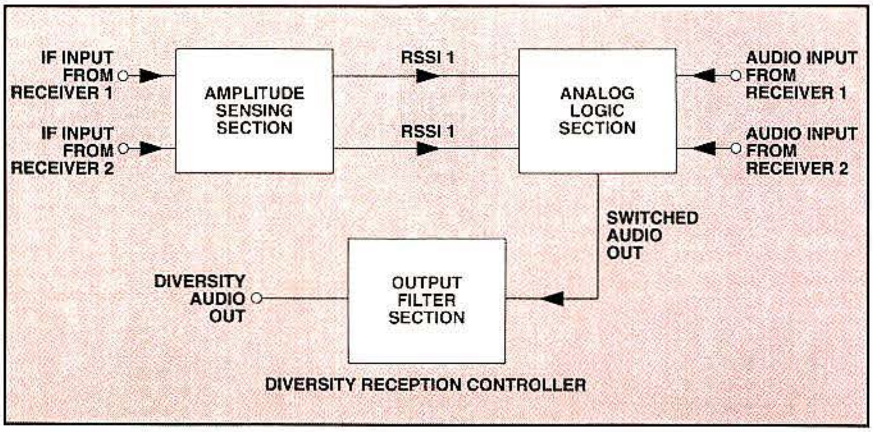


Figure 2. The diversity reception controller includes three main sections: an amplitude-sensing section, an analog logic section, and an output filter section.

receiver is receiving the better signal, and that receiver is then selected. Composite recovered modulation is assembled using a combination, or selection, algorithm. This process is technically complex. It has been largely unsuccessful because RF signal-level quantification circuitry cannot react fast enough to RF amplitude changes, and in the selection algorithm, high-speed switching between discontinuous signals causes damaging transients.

Fortunately, advances in performance along with reductions in the cost of integrated circuitry have enabled the development of a low-cost, highly efficient diversity reception controller that overcomes previous multi-antenna and multi-receiver problems. The controller's *ideal selection diversity* uses multiple receiver outputs that are selected by comparing RF carrier amplitudes.

Figure 2 above is a block diagram of the diversity reception controller, which includes three main sections: an amplitude-sensing section, an analog logic section, and an output filter section.

The amplitude-sensing section contains high-speed, integrated, intermediate-frequency (IF) processors that provide IF amplitude information proportional to the received signal at each antenna. The processors generate an ultra-fast dc voltage received signal strength indicator (RSSI) proportional to the log of received power in decibels over a wide dynamic range.

The analog logic section processes the IF amplitude voltage, receives recovered modulation from the receivers and continuously selects recovered modulation from the receiver with the higher relative received signal.

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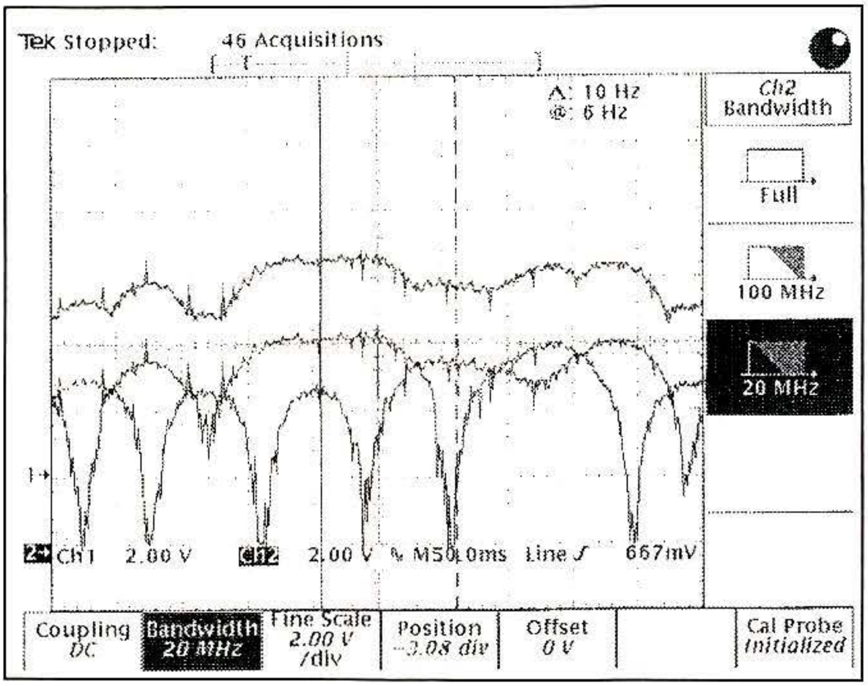

Photo 1. This digital storage oscilloscope display demonstrates the short-term fade reduction that an ideal selection diversity system provides during 500ms of reception in a vehicle traveling at 10mph. The lowest received signal strength encountered by the selected receivers was about –105dBm. Unselected receivers encountered numerous fades, six of which dipped to –130dBm.

Photo 1 at the left and Photo 2 on page 42 are plots taken from a digital storage oscilloscope connected to a diversity reception controller. These plots demonstrate short-term fade reduction that an ideal selection diversity system provides.

Ch1 (the upper trace) is the receivers' RSSI signal selected by the diversity reception controller to supply recovered modulation. Ch2 (the lower trace) displays the RSSI signals of the individual receivers. The diversity reception controller always selects the receiver with the higher relative signal level. This plot was taken in a vehicle traveling about 10mph. The plot is a 500ms snapshot of the short-term fading typically encountered in the mobile environment.

Voltages displayed on the oscilloscope plots correspond to the received signal amplitude as follows:

8.0V	–90dBm
6.0V	–100dBm
4.0V	–110dBm
2.0V	–120dBm
0.0V	–130dBm

As shown in Photo 1, the lowest received signal strength encountered by the selected receivers was about –105dBm.

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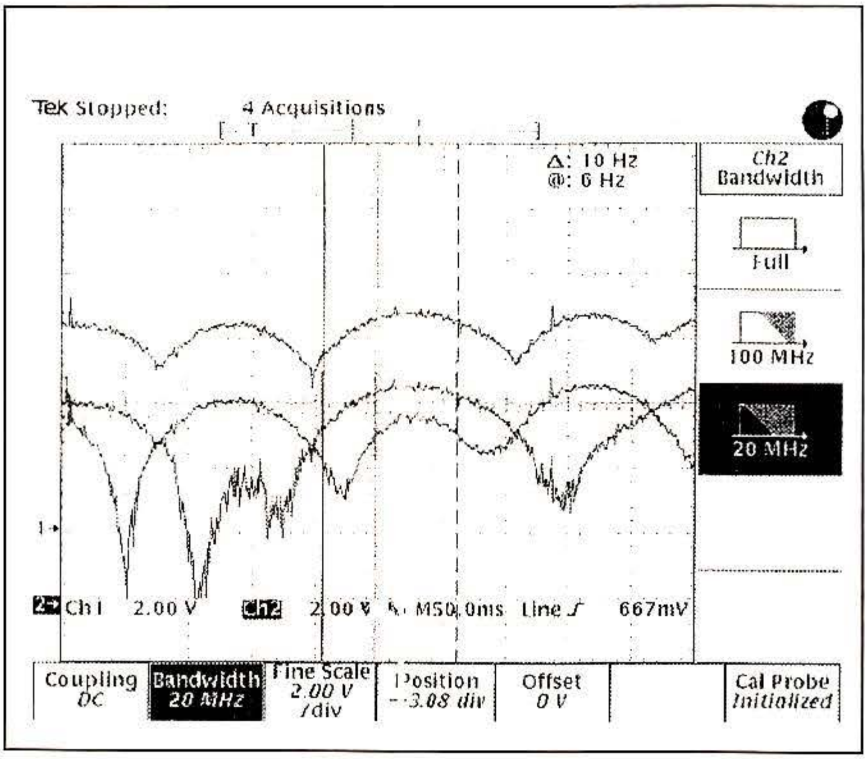

Photo 2. Another 500ms snapshot of typical short-term fading, taken at a slightly slower speed. Clearly evident is the classic shape of a Rayleigh distribution.

Unselected receivers encountered numerous fades, six of which dipped to −130dBm.

Photo 2 is another 500ms snapshot of typical short-term fading, taken at a slightly slower speed. Clearly evident is the classic shape of a Rayleigh distribution.

This diversity reception method's gain is proportional to the fade depth. For example, the percentage of probability of encountering a −10dB fade with ideal selection diversity reception is 1.0%, one-tenth of the percentage of probability without diversity. The percentage of probability of encountering a fade of −20dB with ideal selection diversity reception is 0.01%, one-hundredth of the percentage of probability without diversity.

Figure 3 on page 44 depicts this increase in fade protection. The left side of the graph indicates the percentage of probability of encountering a fade without diversity reception. The right side indicates the percentage of probability with a diversity reception controller.

The increase in performance provided by the diversity controller translates into system reliability. As seen in Figure 3, 99% reliability can be achieved with only a 10dB fade margin, representing a 10dB

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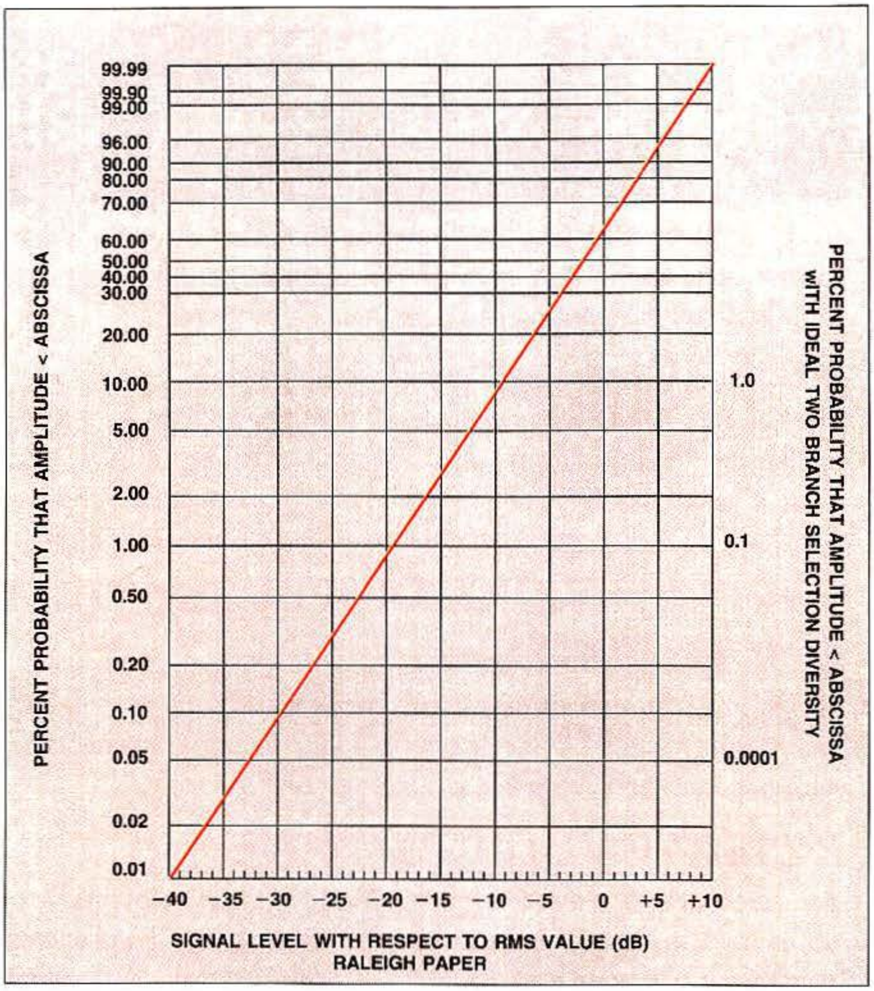

Figure 3. The increase in fade protection for ideal selection diversity reception is proportional to the depth of fades encountered. The left side of the graph indicates the percentage of probability of encountering a fade without diversity reception. The right side indicates the percentage of probability with a diversity reception controller.

improvement over a system without diversity reception. A 99.9% reliability can be achieved with a 20dB fade margin; this represents a 20dB improvement over a system without diversity reception.

Adding diversity reception to an existing radio communications system increases its coverage area and increases its reliability within any given area. For data communications systems, the success rate of first-attempt delivery of data messages rises dramatically, regardless of vehicle speed.

For voice communication, the diversity reception controller provides an 8dB–10dB improvement in signal-to-noise ratio (S/N).

The diversity reception controller can retrofit existing radio systems with the performance advantage of ideal selection diversity reception. An entire fleet can undergo retrofit, or only specific vehicles (such as vehicles that frequent poor coverage areas).

Although the focus of this article has been mainly on the mobile receiver, the base receiver or repeater receiver is subject to the same short-term fading effects as the mobile unit. In terms of performance vs. cost, equipping the system base or repeater station with diversity reception yields the most performance per dollar because the advantages of diversity reception are shared by all users.

A dramatic increase in performance of mobile-to-mobile communications is possible when both repeater and mobile receivers are equipped with the diversity reception controller. The uplink's recovered audio experiences an 8dB–10dB increase in S/N performance. This better-quality audio is repeated on the downlink to a diversity-equipped mobile receiver with an 8dB–10dB increase in S/N performance. The aggregate S/N performance increase can be as high as 16dB to 20dB.

The controller is easy to install with few connections required and is compatible with all existing communications receivers.


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How CDMA is applied to cellular telephone service

Here are the inner workings of the code-division multiple-access (CDMA) technology being implemented by several cellular telephone carriers. Transmitter and receiver test requirements are discussed.

By Ken Thompson and Dave Whipple

The personal communications industry faces an ever-increasing number of users sharing the same limited frequency bands. To expand, the industry must increase capacity without degrading service quality. (See Figure 1 to the right.)

For maximum capacity, analog cellular technology uses complex frequency-division multiple-access (FDMA) with 30kHz channels, directive antennas (cell sectoring) and complex frequency reuse planning.

To increase system capacity, a digital access method, time-division multiple-access (TDMA), is being implemented. It uses the same frequency channelization and reuse as FDMA analog and adds a time-sharing element. Each channel is shared in time by three users to effectively triple system capacity.

The proposed code-division multiple-access (CDMA) cellular mobile telephone system defined by the TIA[1] 45.5 subcommittee is based largely on the system developed by Qualcomm.[2] CDMA uses correlative codes to distinguish one user from another. Frequency divisions are still used, but in a much larger bandwidth (1.23MHz). In CDMA, a single user's channel consists of a specific frequency combined with a unique code.

Thompson is product marketing engineer, and Whipple is research and development technical leader at Hewlett-Packard's Spokane Division, Liberty Lake, WA.

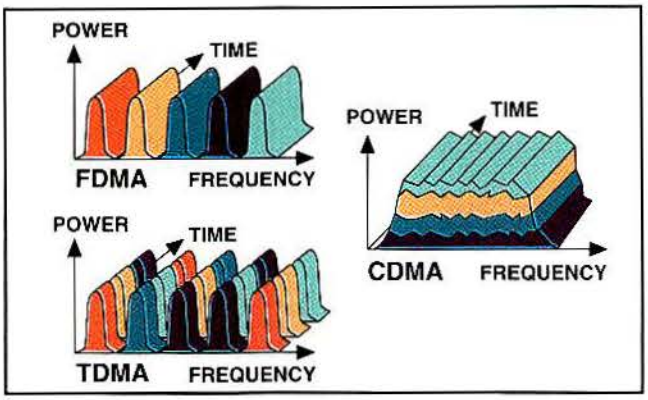

Figure 1. Several access methods are used for cellular mobile telephone service, including frequency-division multiple access (FDMA), time-division multiple-access (TDMA) and code-division multiple access (CDMA). The object of using TDMA or CDMA is to increase capacity without degrading service quality.

The correlative codes allow each user to operate in the presence of substantial interference. An analogy to this is a crowded cocktail party. Many people may be talking at once, but you still can listen to one person at a time. This is because the brain sorts out one voice's characteristics and differentiates them from other talkers. As the party grows larger, each person has to talk louder, and the size of the "talk zone" grows smaller. This would be more dramatic if each conversation were in a different language.

CDMA is similar, but recognition is based on the code. The interference is the sum of all other users on the same CDMA frequency, both from within and without the home cell, and from delayed versions of these signals. It also includes the usual thermal noise and atmospheric disturbances. Delayed signals caused by multipath are separately received and combined in CDMA.

A big part of the capacity gain with CDMA stems from its frequency reuse patterns. The normal reuse pattern for analog and TDMA systems employs only one-seventh of the available frequencies in any given cell. This could really be called frequency non-reuse. With CDMA, the same frequencies are used in all cells. When sectored cells are used, the same frequencies can be used in all sectors of all cells because CDMA is designed to decode the proper signal in the presence of high interference.

CDMA starts with a narrowband signal, shown in Figure 2 on page 48 at the full data rate of 9,600bps. This signal is spread with the use of specialized codes to a bandwidth of 1.23MHz. When transmitted, a CDMA signal experiences high levels of interference, dominated by the coded signals of other CDMA users. This interference takes two forms, interference from other users in the same cell and interference from adjacent cells. The total interference also includes receiver thermal noise, background noise and other spurious signals.

When the signal is received, the correlator recovers the desired signal and rejects other signals and interference. The recovery is possible because all interference sources are uncorrelated to the desired signal.

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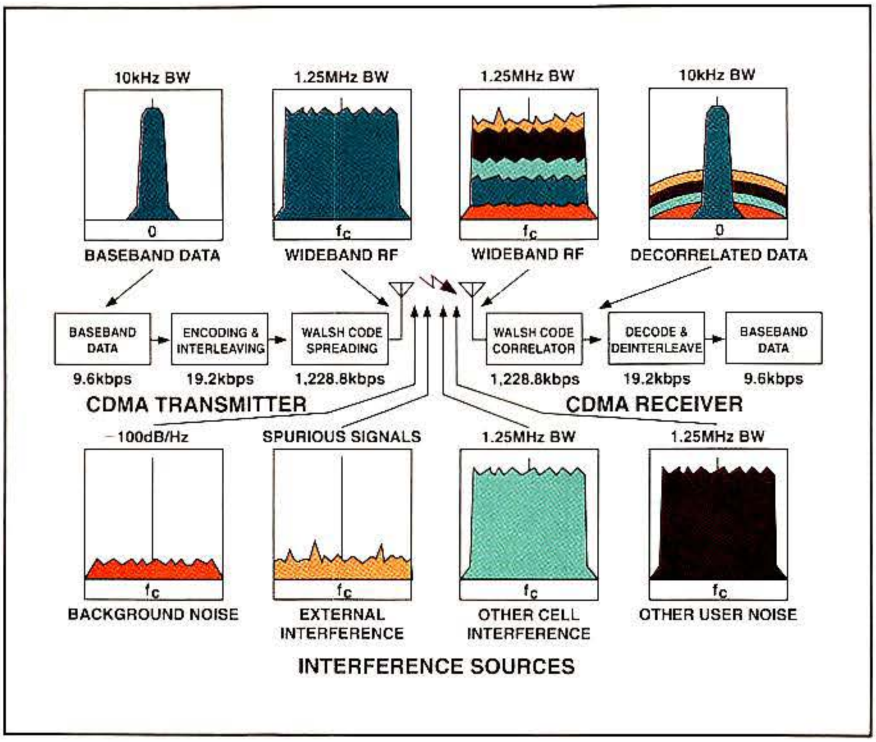

Figure 2. CDMA starts with a narrowband signal at the full data rate of 9,600bps. This signal is spread with the use of specialized codes to a bandwidth of 1.23MHz.

communication systems, a paradigm shift is needed to properly discuss CDMA. Here are some differences between CDMA and analog FM:

□ Multiple users are on one frequency simultaneously.

□ A channel is defined by the correlative code in addition to the frequency.

□ The capacity limit is soft. Capacity can be increased with some degradation of the error rate or voice quality.

Another aspect of CDMA is diversity. CDMA uses three types of diversity: spatial diversity, frequency diversity and time diversity.

Spatial diversity takes two forms:

□ Two antennas: The base station uses two receive antennas for greater immunity to fading, the classical version of spatial diversity.

□ Multiple base stations simultaneously talk to the mobile during soft handoff.

During soft handoff, contact is made with two base stations simultaneously. The signals from the base to mobile are received separately and are coherently combined at the mobile unit. At the base stations, the signals are transmitted via the network to the mobile telephone switching

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office (MTSO), where a quality decision is made on a frame-by-frame basis, every 20ms.

Frequency diversity is inherent in spread-spectrum systems. A fade of the signal is less likely than with narrowband systems. Fading is caused by multipath and is a function of the time delays in the alternate paths. In the frequency domain, a fade appears as a collection of notch filters that move across a band. As the user moves, the frequencies of the notches change. The width of any notch is on the order of one over the difference in arrival time of two signals. For a 1μs delay, the notch is approximately 1MHz wide. The TIA CDMA system uses a 1.25MHz bandwidth, so only those multipaths of time less than 1μs actually cause the signal to experience a deep fade. In many environments, multipath signals arrive at the receiver after a much longer delay. This means that only a narrow portion of the signal is lost. In the display shown in Figure 3 above, the fade is 200kHz to 300kHz wide. This fade results in a power loss to a CDMA signal, but it could result in the complete loss of analog or TDMA signals.

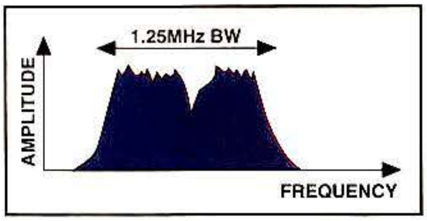

Figure 3. CDMA frequency diversity resists the effects of multipath fading because the fading reduces reception only on a portion of the wideband signal, as a notch filter would.

Time diversity is a technique common to most digital transmission systems. Signals are spread in time by use of interleaving. Forward error-correction is applied, along with maximal likelihood detection. The particular scheme used for CDMA is convolutional encoding in the transmitter with Viterbi decoding using soft decision points in the receiver.

CDMA takes advantage of multipath by using multiple receivers and assigning them to the strongest signals. The mobile receiver uses three receiving elements, and the base station uses four.

This multiple correlator system is called a *rake receiver*. In addition to the separate correlators, searchers are also used to look for alternate multipaths and for neighboring base station signals.

Power control

One of the fundamental enabling technologies of CDMA is power control. The power of all mobile units is controlled so

CDMA makes use of diversity:

Spatial diversity:
- multiple antennas at base station
- multiple base stations for soft handoff

Frequency diversity:
- combats fading caused by multipath
- fading acts as a notch filter to a wide-spectrum signal
- may notch only part of a signal

Time diversity:
- uses rake receiver
- data are interleaved
- convolutional encoding
- Viterbi decoding

their signals arrive at the base station at an equal and minimum level. In this way, the interference from one unit to another is held to a minimum. Two forms of power control are used for the reverse link: open-loop power control and closed-loop power control.

Open-loop power control is based on the similarity of the loss in the *toward path* to the loss in the *reverse path*. (Forward refers to the base-to-mobile link, whereas reverse refers to the mobile-to-base link).

Open-loop control sets the sum of transmit power and receive power to a constant, nominally −73, if both powers are in dBm. A reduction in signal level at the receive antenna results in an increase in signal power from the transmitter. For example, assume that the received power from the base station is −85dBm. This is a composite signal from the base station. The open-loop transmit power setting would be +12dBm.

> **Power control**
>
> **Reverse link power control**
> - all mobiles are received at base station at equal power
> - two types of control
>
>   –open-loop power control
>   - autonomous mobile unit process
>   - assumes loss is similar on forward and reverse paths
>   - 30ms time constant
>   - receive power + transmit power = −73, with all powers in dBm
>   - *Example: for a received power of −85dBm*
>
>   *transmit power = (−73) − (−85)*
>
>   *transmit power = +12dBm*
>
>   –closed-loop power control
>   - directed by base station
>   - updated every 1.25ms
>   - 1dB step size
>   - corrects open-loop power estimate

Closed-loop power control is used to allow the power from the mobile unit to deviate from the nominal as set by open-loop control. This is done with a form of delta modulator. The base station monitors the power received from each mobile station and commands the mobile to either raise power or lower power by a fixed step of 1dB. This process is repeated 800 times per second or every 1.25ms.

Because the power of the mobile is controlled to be no more than is needed to maintain the link at the base station, much less power is typically transmitted from the mobiles than is the case with analog. The analog radio needs to transmit enough power to maintain a link even in the presence of a fade. Most of the time it is transmitting with excess power. The CDMA radio is controlled in real time and is kept at low power. Reduced power has the potential to provide longer battery life and smaller, lower-cost amplifier design. Mobile units support a dynamic range of about 80dB and can be controlled to transmit as little as −60dBm.

Speech encoding

CDMA takes advantage of quiet times during speech to raise capacity. A variable rate vocoder is used; the channel is at 9,600bps when the user is talking. When the user pauses, or is listening, the data rate drops to only 1,200bps. Rates of 2,400bps and 4,800bps are also used, although not as often as the other two. The data rate is based on speech activity, and a decision as to the appropriate rate is made every 20ms.

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Normal telephone speech has an activity factor of about 40%.

The mobile station lowers its data rate by turning off its transmitter when the vocoder is operating at less than 9,600bps. At 1,200bps, the duty cycle is only 1/8 that of the full data rate. The choice of time for this duty cycling is stochastic (randomly variable), so the power is lowered at all times when averaged over many users. Lowering the transmit power at the mobile reduces the level of interference for all other users.

The base station uses a slightly different scheme. It repeats the same bit patterns as many times as needed to get back to the full rate of 9,600bps. The transmit power for that channel is adjusted to reflect this repetition, which allows the interference to be minimized. Repeating the bits at lower power on the forward link is more effective than the reverse link's variable rate transmission technique because it provides greater time diversity and does not rely on the stochastic process of averaging many mobile signals over time.

Forward link coding

An important feature of the forward link is the use of Walsh codes. These codes have the characteristic of being orthogonal to each other and to the logical NOT of each other. Two codes are defined to be orthogonal if they have an exact zero dot product when summed over the full period of the codes. Walsh codes are generated by the expansion shown below:

$$W_{2n} = \begin{matrix} W_n & W_n \\ W_n & \overline{W_n} \end{matrix}$$

where

$\overline{W_n}$ = logical NOT of the bits

The variable, n, in this expansion must always be a power of two. This is seeded with the one-by-one matrix:

$$W_1 = 0$$

The TIA CDMA system uses a 64 by 64 Walsh matrix. (Each Walsh code is 64 bits long.)

Voice data at 9,600bps (full rate) is first passed through a convolutional encoder, which doubles the data rate. (See Figure 4 on page 56.) It is then interleaved, a process that has no effect on the rate, but which does introduce time delays in the final reconstruction of the signal. A long code is XOR'ed with the data, which is a voice privacy function and not needed for channelization. CDMA then applies a 64-bit Walsh code that is uniquely assigned to a base-to-mobile link to form one channel. This sets a physical limit of 64 channels on the forward link. If a bit in the coded voice data is a zero, the Walsh sequence is output; if the data bit is a one, the logical NOT of the Walsh code is sent. The Walsh coding yields a data rate increase of 64 times. The data is then split into I and Q channels, and XOR'ed with short codes. Scrambling the Walsh-encoded data with the short codes allows each CDMA cell site to reuse all Walsh codes without interference. Each CDMA cell site is assigned a unique time offset for its short codes to allow CDMA mobiles to identify each cell site. The final signals are passed through a low-pass filter, and eventually sent to an I/Q modulator.

The *long code* is generated using a 42-bit linear feedback shift register. This is the master clock and is synchronized in all CDMA radios. A specific mask is applied

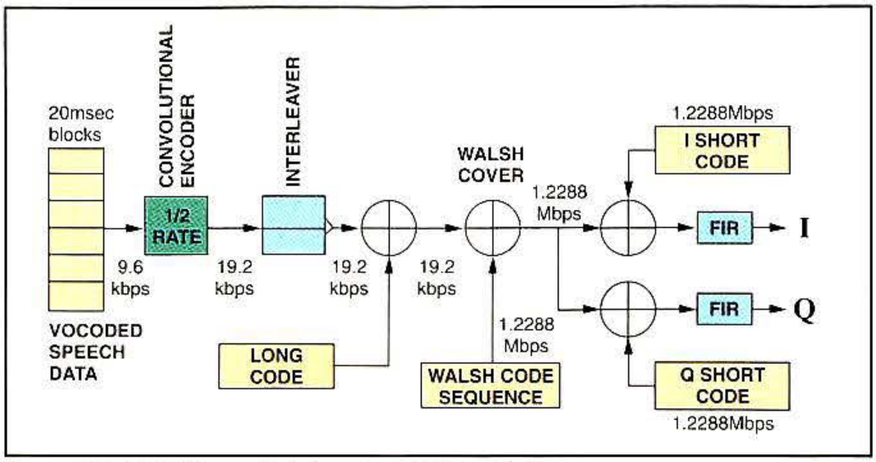


Figure 4. The CDMA forward link (base-to-mobile) physical layer.

to generate a unique long code. On the forward link, bits selected from the long code are used to scramble the user's voice data. (See Figure 5 on page 58.)

The base station transmitter signal is the composite of many channels (with a minimum of four). The *pilot channel* is unmodulated; it consists of only the final spreading sequence (short sequences). The pilot channel is used by all mobiles linked to a cell as a coherent phase reference. The other three channels are the *sync channel*, the *paging channel* and the *traffic channel*, which use the same data flow, but different data are sent on these channels. (See Figure 6 on page 60.)

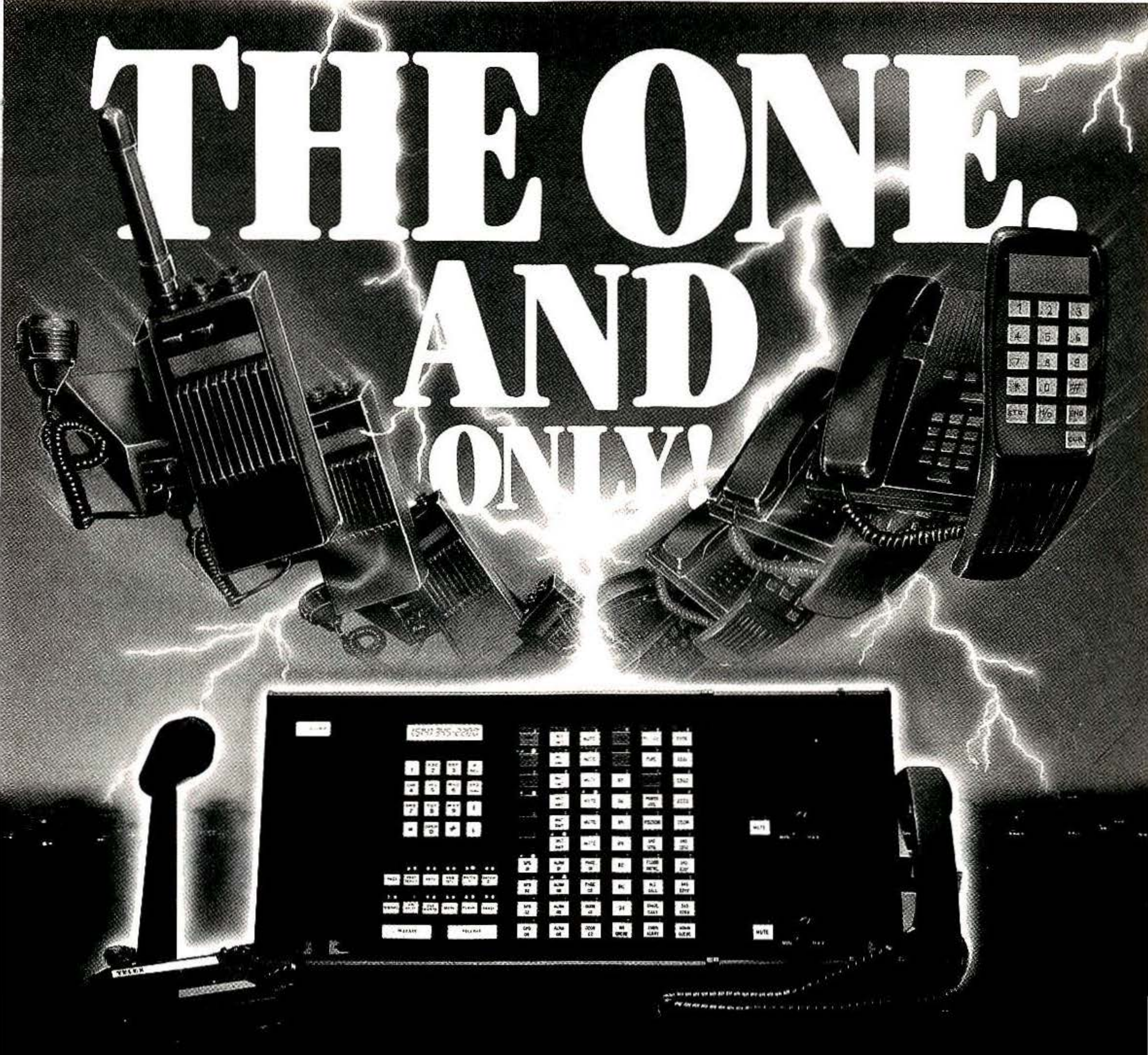
The *sync channel* transmits time-of-day information. This information allows the mobile and the base to align clocks that form the basis of the codes needed by both to make a link.

The *paging channel* is the digital control channel for the forward link. Its complement is the access channel, which is the reverse link control channel. One base station can have multiple paging channels and access channels if necessary.

The *traffic channel* is equivalent to the analog voice channel. This channel is where the actual conversations take place.

Reverse link coding

The CDMA reverse link uses a different coding scheme to transmit data. (See Figure 7 on page 62.) Unlike the forward link, the reverse link cannot support a pilot channel for synchronous demodulation (because each mobile station would need its own pilot channel). In addition, the reverse link cannot use orthogonal codes for channelization because the mobile transmissions cannot be synchronized accurately enough to arrive at the base to maintain orthogonality. To aid reverse link performance, the 9,600bps voice data uses a one-third rate convolutional coded for more powerful error-correction. Then, six modulation symbols at a time are taken to point at one of the 64 available Walsh codes. The data, which is sent at a rate of 307.2kbps, then is XOR'ed with the long code to reach the full 1.2288Mbps data



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rate. This unique long code is the channelization for the reverse link.

The modulation is *filtered QPSK* in the base station and *filtered offset QPSK* in the mobile station. Note that the I/Q diagram for the base station signal is for only a single channel (such as the pilot channel). (See Figure 8 on page 62.) In normal operation, many channels are summed together and transmitted on top of each other by the base station. O-QPSK is used in the mobile stations because it avoids the origin and makes the design of the output amplifier easier. For the base station, because many channels are summed together, using O-QPSK would not always avoid the origin because of the random nature of adding many signals together.

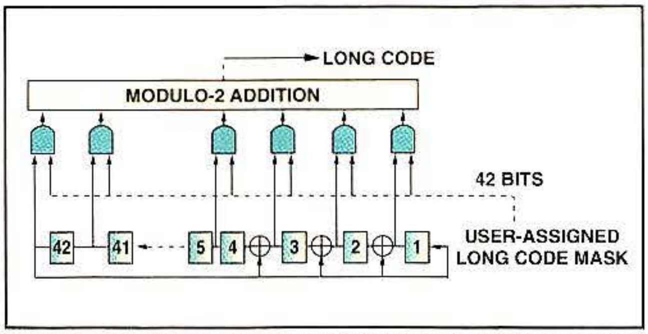

Figure 5. The *long code* is generated using a 42-bit linear feedback shift register.

Signaling

Signaling is well-structured in CDMA. The full data rate of 9,600bps can be shared between data for the user and signaling data. The channel is effectively a modem that can be used for a variety of services. Current standards exist for Service Option 1, the vocoder, and Service Option 2, the data loopback test mode. Service Option 3, the data services test mode, is being balloted by the standards committee.

Test aspects of CDMA

The test aspects can be broken into two major categories: *transmitter test* and *receiver test*.

▶ *Receiver test* — The receiver is required to work in the presence of high interference. For this reason, it is necessary to generate interference as part of the test equipment.

An extra additive Gaussian white noise (AWGN) source is added to the equipment to simulate the interference that is generated by adjacent cells. There is also an interference generator that is time-aligned to the test channel, but on a different Walsh code. This is orthogonal noise and is equivalent to the interference that would come from within the users active cell.

Turning off the interference generators allows the sensitivity to be measured. This is more a measure of the noise figure of the receiver. CDMA radios operate with significant levels of bit errors; the raw channel bits have no inherent information and are not available outside integrated circuits (ICs). The fundamental performance measure is the *frame error rate* rather than *bit error rate*.

▶ *Transmitter tests* — The CDMA transmitter is measured for modulation accuracy, which is defined as the cross correlation between the actual transmitted

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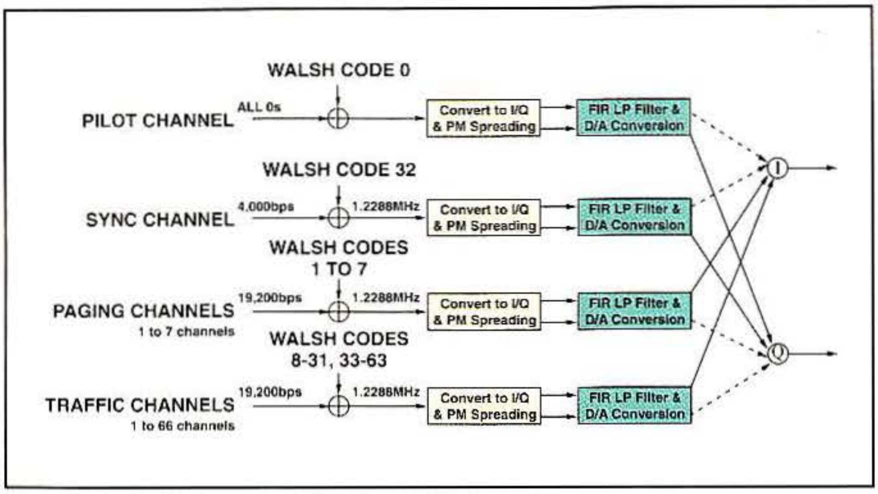

Figure 6. The CDMA forward link (base-to-mobile) channel format.

power and the ideal. This is important, because any uncorrelated power from the transmitter is interference to all users of that frequency.

The measurement must first be corrected for frequency error. The mobile must track the frequency of the base station within 300Hz. The modulation accuracy measurement also measures frequency. Power control needs to be checked; both closed-loop and open-loop.

Open-loop is checked by setting the power at the antenna port to a calibrated level and measuring the level of the transmitter. Varying the level of the test source should also vary the mobile station's output power.

Closed-loop power control is measured by setting the power control bits to specified sequences and verifying the power response of the mobile unit. It is necessary to establish a link to make this measurement.

Typical CDMA call scenario

"Ten Minutes in the Life of a CDMA Mobile Station" starts with the turning-on of the radio and system access. It assumes that the user is moving through the network. It covers call initiation, soft handoff and call termination.

▶ *System access* — When the mobile first turns on, it must find the best base station. This process is similar to that in an analog system where the phone scans all of the control channels and selects the best one. In CDMA, the mobile unit scans for available *pilot signals*, which are all on different time offsets.

The process is made easier because of the fixed offsets. The timing of any base station is always an exact multiple of 64 system clock cycles (called chips) offset from any other base station. The mobile selects the strongest pilot tone and establishes a frequency and time reference with this signal.

The mobile then demodulates the sync channel, which is always on Walsh 32. This channel provides master clock

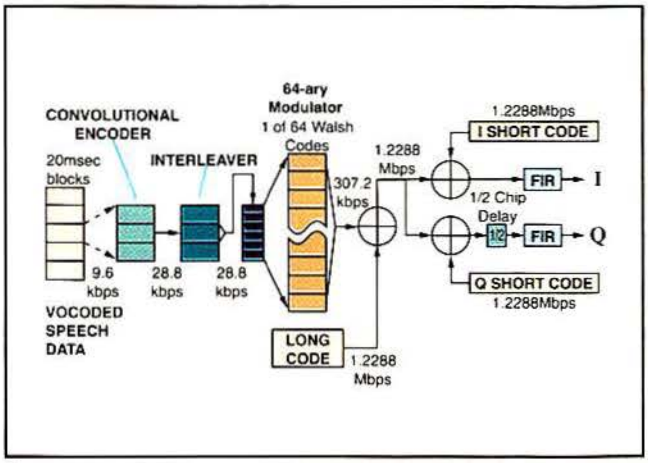

Figure 7. The CDMA reverse link (mobile-to-base) physical layer.

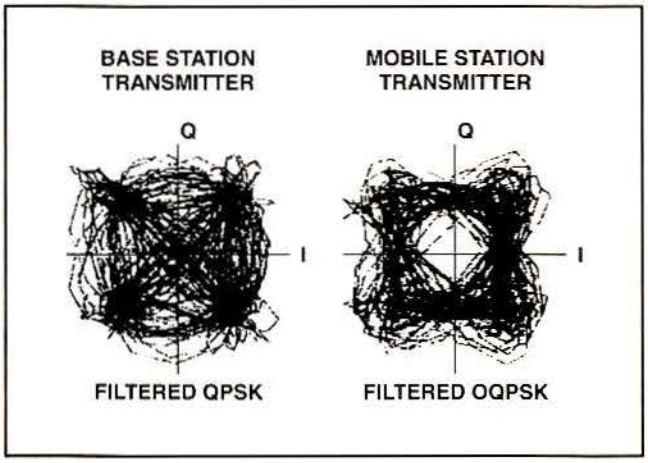

Figure 8. CDMA modulation formats.

information by sending the state of the 42-bit long code shift register 320ms in the future. The *sync channel message* also contains many other system parameters. The mobile then starts listening to the paging channel and waits for a *page* directed to its phone number. The mobile often registers with the base station so that the base station can conduct zone-based paging rather than system-wide paging.

The user then decides to make a call. The number is keyed in, and the send key is pressed. This step initiates an *access probe*. The mobile uses the *access channel* and attempts to make contact with the serving base station. Because no link is yet established, closed-loop power control is not active. The mobile uses open-loop control to guess an initial level.

Multiple tries are allowed with random times between the tries to avoid collisions that can occur on the access channel. After each attempt, the mobile listens to the paging channel for a response from the base station. The base station responds with an assignment to a traffic channel. This is a Walsh code for the forward link. The traffic channels use different long codes than the paging channel. The base station initiates the land link, and a conversation can take place.

During the call, the mobile finds yet another base station with good power. The

mobile makes a request from its serving cell to initiate soft handoff with the additional cell. The base station passes this request to the MTSO, which contacts the second base station and gets a Walsh assignment. This assignment is sent to the mobile by the first base station. The land link is connected to both base stations. The mobile combines the signals from both base stations by using the two pilot signals as coherent phase references. At the MTSO, the signals are examined from each base station, and the better one is chosen for each 20ms block.

As the signal from the first base station degrades, the mobile will ask that the soft handoff be terminated. At this point, the mobile is being power-controlled by the second base station (because the first cell probably has a very poor link). In soft handoff, the rule for closed-loop power control is that the mobile unit's power will be increased only if *both* base stations request an increase. The request is passed from the second cell through the MTSO, and the first cell stops transmission and reception of the signal. The mobile is now only on the second cell.

Finally, the call ends. Call termination can be initiated either from the mobile or the land side. In either case, transmissions are stopped and the land line connection is broken.

Ten minutes in the life of a CDMA mobile phone

- **Turn on**
  - –system access
- **Initiate call**
  - –system access
- **Continue travel**
  - –initiate soft handoff
  - –terminate soft handoff
- **End call**

Conclusions

CDMA provides an advanced technology for cellular applications. It provides high-quality service to a large number of users. It is a system that has been extensively tested, and it was deployed in 1994 in pre-commercial applications. Commercial service is scheduled to begin in 1995.

CDMA mobile test requirements:

- **Receiver test**
  - –requires multiple sources
    - pilot
    - sync
    - traffic
    - noise — orthogonal
    - noise — uncorrelated
- **fundamental measure is FER**
- **Transmitter test**
  - –modulation accuracy
    - correlated power
    - frequency
  - –power control
    - open-loop
    - closed-loop
- **fundamental measure is waveform quality**

Acknowledgment

The authors would like to thank Chuck Wheatley of Qualcomm for reviewing this article.

Paging reliability tests help to increase subscribers

Technical measurements can help paging carriers to ensure customer satisfaction. Using portable equipment with extensive analysis capabilities speeds tests and keeps measurement costs within reason.

By Tim Garrett

Success for a paging carrier depends on the ability to provide proper service quality at a reasonable price to maintain profitability and subscriber growth. Many business and technical factors contribute to a carrier's ability to meet these objectives. Some primary technical factors that must be monitored in a paging system include:

- signal strength vs. geographic location (how well the signal is received throughout the coverage area).
- interference from other paging carriers and radio communications services (whether and how much other radio signals disrupt reception).
- system efficiency and throughput performance relative to the paging standard and data format (how quickly messages are transmitted to the recipient after they are received by the carrier, with results sorted according to POCSAG, Golay, NEC and Flex standards and by numeric and alphanumeric formats).

The capability to monitor, quantify and track these factors is key to the long-term success of the paging business. Failure to monitor and track all of the relevant factors can lead to erroneous conclusions about causes when problems arise and can waste time and money during preventive maintenance. The paging carrier's challenge is to select and to learn to use a cost-effective test and measurement instrument that measures and analyzes the key technical factors to reveal solutions to problems or suspected system deficiencies.

Garrett is vice president, new technology, Grayson Electronics Division of Allen Telecom Group, Forest, VA. The PageTracker Pro made by Grayson is the portable wireless measurement tool described in this article.

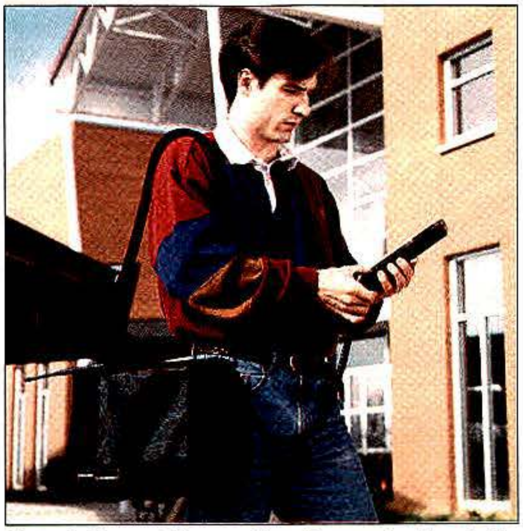

Photo 1. For portable operation, the operator inserts the wireless measurement tool's receiver assembly into a shoulder bag and controls the unit with a hand-held device. Measured data are recorded on an internal random-access memory (RAM) card.

Signal strength vs. location

Most paging carriers take signal strength vs. geographic position measurements. Usually, a technician equipped with a pager is dispatched to travel throughout the coverage area and manually log locations where the pager receives proper messages. A less desirable method is to log customer complaints about lack of service in particular locations.

As methods go, waiting for complaints is unacceptable because the point is to prevent customer dissatisfaction. Dispatching a technician to log paging message reception is undesirable because the method measures only one of the relevant technical factors necessary to reveal system problems and their solutions. Moreover, the manual technique depends heavily on the technician's skill and the pager's characteristics—both may affect reception one way or the other. Managers at most paging carriers that have used the manual technique for years are realizing that a more automated measuring technique is required to identify system problems properly and to implement solutions.

Cellular carriers, by the way, face many of the same problems as paging carriers to identify system problems and to devise solutions. Cellular carriers often drive a specially equipped van throughout the service area to gather large amounts of performance data for later analysis by their engineering departments. Performance data that such vans can measure usually are confined to cellular frequencies because the receiver is a cellular phone operating in its test mode. Additionally, the cost of such measurement vans ranges from $100,000 to $250,000, and they cannot be used for portable measurements inside buildings.

Measuring all relevant factors

A suitable measurement tool for paging carriers would measure all of the relevant performance factors and would be small, lightweight and economically priced. Portable operation is required because many routine coverage problems occur inside office buildings and other enclosed structures. Laboratory-grade hardware is necessary to ensure that data measurements are accurate and repeatable. Manual operation is essential to support specific engineering tasks in addition to automatic operation for use by less-skilled operators performing more routine tasks. Granted that the accumulation of measured data is indispensable, software tools are equally important to analyze measured data and to present concise answers or reports about suspected problems.

One portable wireless measurement tool designed to meet these requirements, with the help of a laptop computer, simultaneously measures signal strengths, decodes paging messages, "time-stamps" the measurement and records the geographic location for each measurement on a maximum of four frequencies in any of the standard paging frequency bands. For portable operation, the operator inserts the receiver assembly into a custom-designed canvas bag and controls the unit with a hand-held device while measured data are recorded on an internal random-access memory (RAM) card. (See photo 1 on page 65.) This combination of hardware and software overcomes many of the problems associated with less-sophisticated measurement techniques.

Receivers and decoders

The hardware consists of a rugged metal enclosure for as many as four plug-in receiver modules and their associated digital signal processing-based (DSP) data decoder, a Global Positioning System (GPS) receiver for position-stamping, a RAM card for data storage and an MC68306 microprocessor that controls all of the hardware functions and the RS-232 port. Housed in a metal enclosure to shield them from radio-frequency interference (RFI), each custom-designed receiver module meets laboratory performance standards. Receiver modules are available for the 150MHz, 450MHz and 900MHz frequency bands, and each receiver can scan a maximum of 100 channels per second. A splitter-amplifier module connects each receiver to the common antenna port on the front of the metal enclosure and provides the appropriate amount of gain and selectivity to ensure optimum performance in each band.

If the user does not need this common antenna port, the receiver enclosure may be equipped with an individual antenna connector for each receiver. The DSP-based decoder accepts baseband information from its associated receiver and decodes messages for POCSAG, Golay, NEC and Flex paging standards.

Operating modes

The three basic operating modes are *scan*, *record* and *key page*. These software modes control the hardware to decode, record and display paging messages received by the four individual receivers. This combination of hardware and software provides the paging carrier with a portable wireless measurement tool capable of measuring, analyzing and recording all of the data required to maintain a profitable business.

▶ *Scan mode* — The scan mode monitors assigned frequencies from a user-generated scan list and records channel activity vs. time, geographic location and frequency band. Each of the four receivers can scan and record radio-frequency (RF) activity at a maximum rate of 100 channels per second, which results in a fast, comprehensive look at a wide frequency spectrum. All of this "frequency activity information" is "stamped" simultaneously with time and geographic location. When used with mapping software, signal strength data can be used to generate paging coverage contour maps. (See Figure 1 on page 68). An additional application for the scan mode is to identify and quantify interference sources as a function of time and geographic location.

▶ *Record mode* — The record mode decodes all of the paging messages from each of the four receivers, adds a time

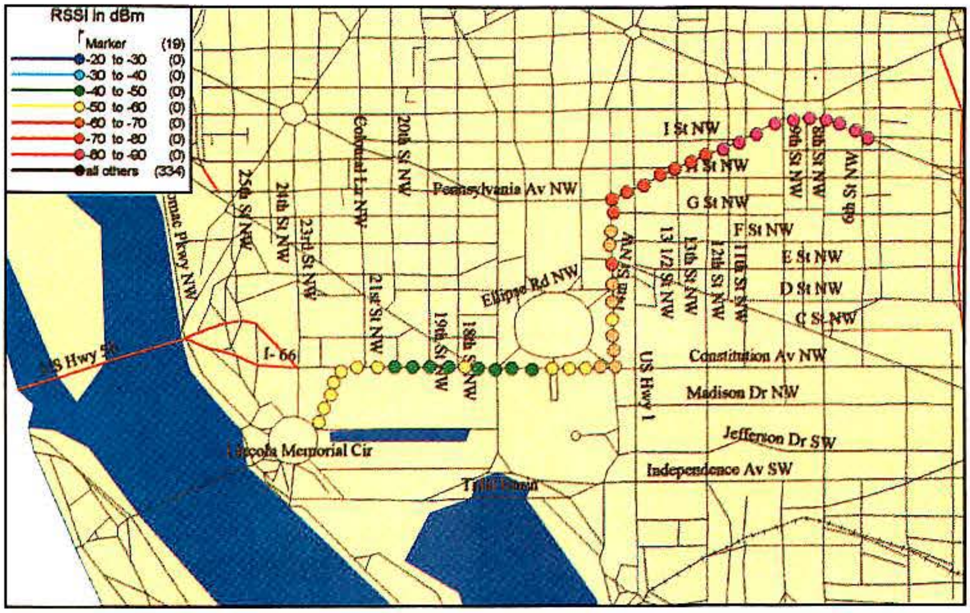

Figure 1. Mapping software can process signal strength data to plot position information together with the signal strength. With enough measurements, paging coverage contour maps can be drawn.

and position stamp and records the data. The user can define a setup mask to display the percentage, number and length of paging messages as a function of any of the standard paging formats, including Flex. An additional function of the record mode is the capability of recording the time-, date- and position-stamped list of batch efficiency for each paging message.

▶ *Key page mode* — The key page mode screens paging traffic from all four receivers in real time to selectively receive only certain pages, message lengths, capcodes or paging standards. The user defines the screen characteristics and can change them any time. An unlimited number of trigger profiles are available to the user for virtually any test that may be necessary.

With suitable hardware and software, paging carriers can make the measurements and conduct the analyses necessary to maintain a level of paging system performance that meets customer expectations. A portable wireless measurement tool can make the difference in revealing system deficiencies and indicating solutions to problems.

(continued from page 8)

isolation, and more isolation could be obtained by inserting isolation amplifiers between the generator outputs and the combiner.

Of course, proper padding must be used to maintain a good impedance match throughout. Just remember, the setup shown in Figure 2 is a simplified version of the elaborate setup used in laboratories.

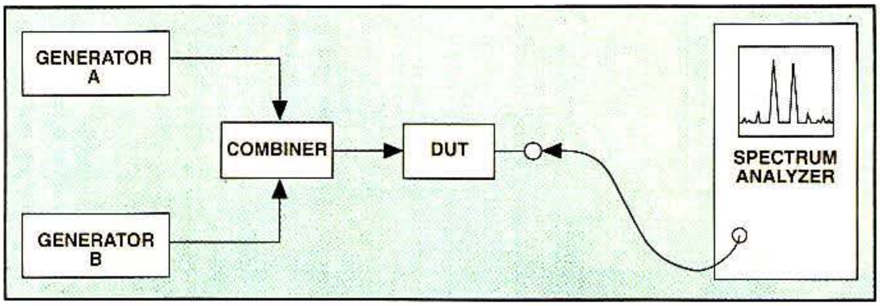

Figure 5. A device under test (DUT) is tested for third-order intermod using this simplified version of the laboratory setup. See text for information about the integrity of the test setup.

The whole purpose is to make sure that any IMD *caused by the test setup* is suppressed far below the IMD generated in the device under test (DUT)—in this case, the spectrum analyzer.

Dynamic range

Gradually increase the generators' outputs at equal levels until the third-order intermod products just begin to appear above the noise level on the spectrum analyzer display. At this point, the difference between the level of tone A (or B) and one of the intermod products (2A – B or 2B – A) is called the *dynamic range* of the spectrum analzyer. For example, when the difference between tone A and the 2A – B product is 70dB, the dynamic range of the spectrum analzyer is 70dB. (See Figure 3 on page 8.)

Third-order intercept

Once the intermod signals form, the levels of the IM signals increase rapidly as the level of the two tones increases. In fact, the level of the IM signals increases much more rapidly than the level of the fundamental tones (A or B). For this reason, theoretically, a point would be reached where the level of the IM signals would become equal to the level of the fundamental tones, A or B. (See Figure 4 on page 8.) This point is called the *third-order intercept point.* This point occurs when the input tones are increased about 15dB above the point of 1dB compression.

Remember, the third-order intercept point exists only *in theory.* In practice, an amplifier's compression prevents IMD signals from reaching this point. Regardless, the third-order intercept point is an important specification for amplifiers and receivers. It tells a lot about how the amplifier or device should be operated. Although higher-order intercept points could be specified, third-order intermod is the most prominent and therefore the most troublesome.

Figure 5 above shows how a typical

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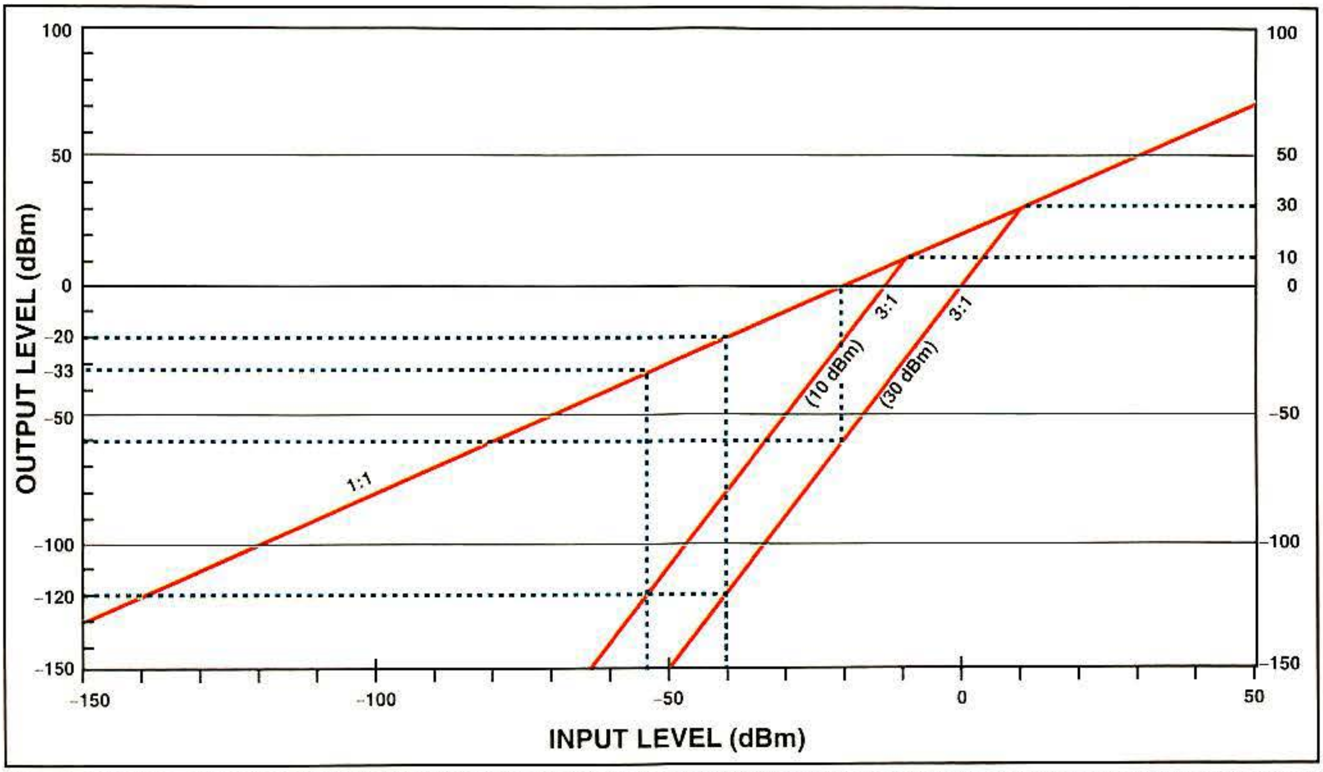

Figure 6. This graph of the third-order intercept point of two amplifiers is useful in determining the amplifier's operating conditions, input/output levels and IM levels. See text for details.

DUT is tested. This configuration could represent receiver testing. The spectrum analyzer could be connected to the first IF amplifier's output or another such test point in the receiver. The test would include all circuits between the receiver input and the point of measurement. However, the first *active* device will be the main determining factor.

Third-order intercept graph

Figure 6 on page 69 shows the third-order intercept points for two amplifiers. Both amplifiers have 20dB gain. One has a third-order intercept point of +30dBm; the other has a third-order intercept point of +10dBm.

Notice that there are three graphs. One represents the amplifier's linear output vs. input—the 1:1 ratio line that means that the output (vertical scale) changes 1dB for each 1dB change in input (horizontal scale). The other two lines representing the intermod signals have a 3:1 slope, which means that, with a 1dB change in the input level, the output level will change by 3dB. The point where the 3:1 graph intersects the 1:1 graph is the third-order intercept point. Notice that one point is at +30dBm, and the other is at +10dBm.

Third-order intercept formulas

These formulas take into account the DUT's gain and are based on the input signal levels.

$$I_P = \left(\frac{3(P_{Ai} + G) - P_3}{2}\right) \quad (1)$$

$$P_3 = 3(P_{Ai} + G) - 2I_P \quad (2)$$

$$P_{Ai} = \left(\frac{(P_3 - 3G = 2I_P)}{3}\right) \quad (3)$$

where

P_3 = power (dBm) in third-order intermod signal.

P_{Ai} = power (dBm) of either tone A or tone B at the *input*.

G = gain (dB) of amplifier.

I_P = third-order intercept point (dBm).

These formulas represent the levels of tone A and tone B at the point where the spectrum analyzer is connected.

$$I_P = \left(\frac{3P_A - P_3}{2}\right) \quad (4)$$

$$P_3 = 3P_A - 2I_P \quad (5)$$

$$P_A = \left(\frac{(P_3 + 2I_P)}{3}\right) \quad (6)$$

where

P_3 = power (dBm) of third-order intermod signal.

P_{Ai} = power (dBm) of either tone A or tone B.

I_P = third-order intercept point (dBm).

The graph takes into account the amplifier's 20dB gain. For example, an input level of –40dBm (horizontal scale) corresponds to an output level of –20dBm (vertical scale).

Suppose a receiver has a sensitivity of –110dBm or 0.7μV. To prevent the third-order IM signal from degrading the reception of a –110dBm signal, the IM signal should be suppressed at least 10dB *below the desired signal level*. In this case, the third-order IM signal should be no greater than –120dBm to prevent any interference to the desired signal.

To determine the maximum input/output level that the have two tones can reach before causing distortion, a line is drawn from the –120dBm point on the vertical scale to intersect the IM slopes. Then, vertical lines are drawn up to the 1:1 slope and down to the horizontal scale. These lines are shown as dashed lines in Figure 6. The dashed lines intersect the 1:1 slope at the –20dBm point for the +30dBm slope and at –33dBm for the +10dBm slope.

The IMD ratio can be defined as the difference in the level of the desired tone (A or B) and the level of the third-order IM signal measured in decibels.

Similarly, the dashed lines intersect the horizontal scale at –40dBm for the +30dBm slope and –53dBm for the +10dBm slope. Thus, for the +30dBm slope, the output level of tone A or B should be no greater than –20dBm, and the input level to the amplifier should be no greater than –40dBm.

For the +10dBm slope, the output level of tone A or B should be no greater than –33dBm, and the input level should be no greater than –53dBm. If the input/output levels exceed these limits, the third-order IM signal will exceed the –120dBm level and will degrade the –110dBm desired signal.

IMD ratio

The IMD ratio can be defined as the difference in the level of the desired tone (A or B) and the level of the third-order IM signal measured in decibels.

The IMD ratio must be specified at a given input or output level because the IMD ratio becomes worse as the input/output level increases.

Take the case of the 20dB amplifier with the +30dBm third-order intercept point. When the output level of tone A or B is -20dBm, the level of the third-order IM signal is -120dBm. This difference represents an IMD ratio of (-20) - (-120) = 100dB.

Now, look at the case for an output level of 0dBm. As shown by the dashed line, the third-order IM signal is -60dBm. Thus, the IMD ratio is now 60dB. The ratio gets worse fast as the input/output level increases!

Formulas

You can use formulas listed on page 70 to make calculations involved with third-order intercept. Formulas 1-3 take into account the DUT's gain and are based on the *input* signal levels. This means that the spectrum analyzer used to study the intermod is connected to the *output* of the device, and the signal levels used in the formulae (P_{Ai}) are the levels of the tones (A or B) at the input to the device.

Formulas 4–6 represent the levels of the tones (A or B) at the point where the spectrum analyzer is connected. These examples demonstrate the practical use of the formulas.

Example: The DUT is an RF amplifier with 20dB gain and a +20dBm third-order intercept point. The level of the third-order IM signals must be kept to no more than -60dBm. What is the maximum level of tone A or B short of causing IM signals greater than -60dBm?

Solution: Use Formula 3 on page 70 and substitute values from the example.

$$P_{Ai} = \left[\frac{-60 - 3(20) + 2(20)}{3}\right]$$

$$= \left(\frac{-80}{3}\right)$$

$$= -26.7dBm$$

Example: The DUT is an RF amplifier. A spectrum analyzer connected to the output shows the third-order IM signal at a level of -60dBm and the level of tone A at -10dBm. What is the third-order intercept point?

Solution: Use Formula 4 on page 70 and substitute values from the example.

$$I_P = \left[\frac{3(-10) - (-60)}{2}\right]$$

$$= \left(\frac{+30}{2}\right)$$

$$= +15dBm$$

Next time, we will look at intermodulation from a different perspective and learn how to take advantage of the behavior of the third- and higher-order intermodulation process to gain an advantage in suppressing it. *Stay tuned!*

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2. Mann, Ernest N., *An Introduction to Radio Frequency Theory*, 1988, Mannbros Technologies, Augusta, ME.

3. Smith, Jack, *Modern Communication Circuits*, 1986, McGraw-Hill, New York.

Believe it or not

By Robert H. Schwaninger Jr.

It has been my experience that many telecommunications systems operators are unaware of many facts, circumstances and laws that can affect the manner in which they do business. Following are little tidbits of information that can alter one's view of the industry or simply make for interesting cocktail party chatter—that is, if the people at the party are radio system operators and not members of the general public, whose eyes tend to glass over when we speak in our version of "techno-legalbabble."

Over the years, I have collected a number of war stories, interesting snippets of data and law, and some generally amusing stuff. This information may be useful. If not useful, then maybe the information will be amusing. If not amusing or useful, then maybe it will serve as the basis for further changes in the Communications Act, because Congress often uses information that is neither useful nor amusing to motivate its members.

* * *

The Communications Act mandates a one-year statute of limitations for violations of the FCC Rules. Be careful using this information. The question that you need to ask is *When does the one-year period begin to run?*

* * *

Despite FCC claims to to the contrary, *there is no Wireless Telecommunications Bureau operating under law* within the agency. For a new bureau to have legal authority, the FCC must publish rules that delegate authority to the new bureau. No notice of such delegation of authority has been published as of Jan. 20.

* * *

Morgan O'Brien, chairman of Nextel Communications, was quoted within the past few weeks as claiming that he never said that Nextel would be the third cellular provider. *Someone should tell the FCC of Nextel's diluted claims* as the agency wrestles with the issue of regulatory parity among various types of wireless telecommunications carriers.

* * *

To the best of my knowledge, only one entity has ever been allowed to use Railroad Radio Service frequencies under authority of the FCC's interservice sharing rules. The singular approval was granted under *threat of intervention by former U.S. president George Bush.*

* * *

A former FCC licensee was found to have abused its license for operation of a Public Coast Radio Service station when the commission found that the station was using Special Emergency Radio Service channels to order liquor supplies for a brothel. In defense, a representative of the licensee said, "When you run out of liquor at a whorehouse, it *is* a special emergency."

* * *

The FCC took two years to decide a matter that arose out of allegations that one of the parties involved in a dispute had transferred control of a radio communications facility without FCC authorization. In its decision, the FCC stated that, *given the passage of time*, the issue had become moot.

* * *

The FCC rules require that a licensee must be willing to *testify against itself*, even in matters alleging criminal activity. Obviously, *the Fifth Amendment to the U.S. Constitution was circumvented, ignored or overturned* somewhere along the line by the commission's administrative notice-and-comment rulemaking.

* * *

While interviewing former president Jimmy Carter, CNN anchor Bernard Shaw said that his network had *intercepted one of Carter's private conversations* when it was carried by radio communications from the plane to a land-based facility as Carter returned to the United States from Haiti. *The statement amounts to an admission of violating FCC rules against making use of the content of intercepted radio communications.* Thus far, I know of no FCC effort to fine the news organization for a breach of the confidentiality rules.

* * *

Nextel Communications has never been given authority to operate as an entity eligible for a Commercial Mobile Radio Service license because the FCC has yet to act on the company's request for a waiver of the foreign ownership rules. The waiver request has been pending for more than a year.

* * *

Included among issues required to be covered in environmental impact studies for constructing a new radio tower is whether the facility will interfere with "nocturnal migratory fowl." *It seems as though some geese don't know when to duck when it's dark.*

* * *

Rarely is the FCC required to take any specific action within a certain time limit. One exception is that *the FCC has 10 days to respond* to requests for information filed under provisions of the Freedom of Information Act.

* * *

FCC precedent allows applicants, under certain circumstances, to extend filing deadlines by one day. This precedent arose out of the fact that *most telecommunications lawyers are procrastinators and know the art of effective whining.*

* * *

In the recent *Capital Radio Telephone* case, the administrative law judge found that the Private Radio Bureau (PRB) had, in fact, *prosecuted the victim.* One wag stated, "This was a first. The PRB normally *persecutes* the victim."

* * *

Finally, the FCC requires local exchange carriers (telephone companies) that experience service outage to more than 50,000 lines to *call* the FCC and notify it of the problem. *Sounds like standing in front of a room and asking for a show of hands from the absentees.*

* * *

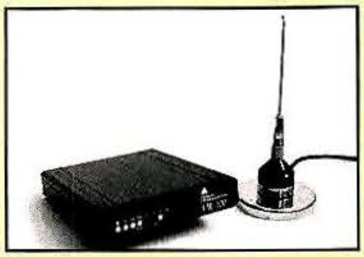
You are invited to send me a letter describing *your* bizarre regulatory experiences. The writer of the best letter, to be judged only by me because I don't want to split the bribes, will receive a copy of the Communications Act—*which the U.S. General Printing Office says has been out of print since February 1993.*

Schwaninger, *MRT's* regulatory consultant, is a partner in the law firm of Brown and Schwaninger, Washington, DC. He is a member of the Radio Club of America.

Readers' choice

Of all the new products and services in the July 1994 issue, the one reprinted here generated the most reader requests for additional information. If you missed it the first time, here is your opportunity to acquire more information on it. Just circle the corresponding Fast Fact Card number on the card found in the back of this issue and mail the card to us.

Vehicular repeater extends UHF hand-helds' range



The VR-100 low-power vehicular repeater from **Pyramid Communications** provides extended range to UHF hand-helds by crossband repeat operation with an existing mobile. The VR-100 is Motorola PAC/RT-compatible and provides features for "first man out" priority sampling, multi-vehicle operation and local mic repeat. Jumper-selectable options include conventional/trunking applications, lock tone frequency, priority sample rate, COR polarity, remote enable polarity and flat or 6dB/octave audio response. The VR-100 is 5.25"W × 6"L × 1.1"H and weighs 18oz.

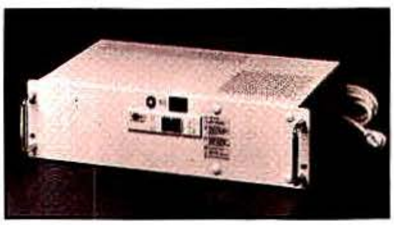
Circle (500) on Fast Fact Card

SMR network offers full-featured voice, data services

Ericsson's PCN (Private Communications Network) has integrated voice and data services for the SMR market. PCN is based on Ericsson's EDACS digitally trunked wireless communications system. PCN allows operators to construct a shared SMR system to provide dispatch, telephone and data network services. PCN's features include mobile data transmission at 9.6kbps on all channels that supports field service reporting, AVL and fax applications; larger cell sizes; dispatch capability; phone service with voice messaging and call forwarding; and paging and centralized diagnostics.

Circle (351) on Fast fact Card

Line-interactive UPS units monitor power status



The Smart 750 RM and Smart 1250 RM rack-mount uninterruptible power supply (UPS) systems from **Tripp Lite** are designed for installation in standard 19" racks. Both feature eight ac outlets, detachable rack handles, a recessed front-mount master switch and metal casing. Both units are microprocessor-controlled, line-interactive UPS units with communications and monitoring capabilities for both power status and network interaction. Other features include full-time voltage regulation, spike and noise filtering, battery testing, remote control and reboot.

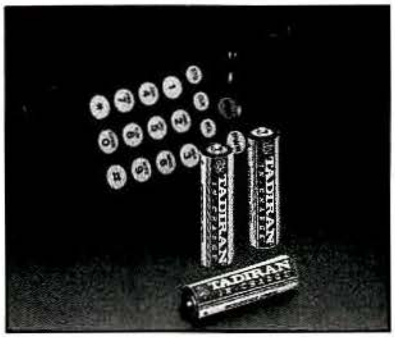
Circle (352) on Fast Fact Card

Adapter kit serves in-series and between-series needs

RF Industries' RFA-4027 SMA Technician's Adapter Kit includes the 13 most popular SMA adapters. It also contains both in-series and between-series adapters. The adapters are housed in a rugged, zippered, leatherette case designed for easy carrying or storage. All adapter sections are made of nickel-plated machined brass with gold-plated contacts anchored in Teflon dielectrics.

Circle (353) on Fast Fact Card

Rechargeable battery provides high energy density



The TLR-7103 "In-Charge" AA rechargeable lithium battery from **Tadrian Electronic Industries** is designed to have an energy density 50% greater than NiMH or lithium ion equivalents and 250% greater than NiCd equivalents. The battery features a safer, patented cell chemistry, high capacity retention, no memory effect, a broad operating temperature range and no heavy metals. Discharge current performance is as high as 2A, continuous and pulse, with a flat discharge curve.

Circle (354) on Fast Fact Card

Numeric pager supports Flex, POCSAG formats

NEC America's NEC Facts Exec numeric pager uses both the Flex and POCSAG formats. Incorporation of the Flex format is designed to increase subscriber capacity for the system operator and battery life for the individual user. The NEC Facts Exec is the company's smallest offering to date, measuring 2.5" × 1.81" × 0.78" and weighing 2.19 ounces. Features include three-button operation, message memory, clock and time stamp, multiple user-selectable alert modes and a 12-character backlit display.

Circle (355) on Fast Fact Card

Modem modifies radios for transfer of electronic data

Trident Micro Systems has introduced the M-12 Data Modem. The M-12 is a small PCB designed for easy installation into a trunked or conventional radio, regardless of brand, for the transfer of electronic data from PC to PC. The modem also will transfer programming information to the Trident TNT-100, 110, 120 or CR-355 and does not interfere with the other operations of the controller or call router. Data will transfer in blocks as large as 2K. Auto error correction will resend any data that is recognized as corrupted by the receiving modem. The manufacturer recommends ProComm Plus software by Datastorm Technologies for PC communications using the X-MODEM protocol.

Circle (356) on Fast Fact Card

Digital voice recorder provides non-volatile security

Sigtronics' digital voice recorder instantly records information from dispatch to be played back later, helping to reduce radio traffic. Both sides of radio and intercom conversations can be recorded. The recorder is non-volatile; messages will not erase with loss of power, only when recorded over. The unit is compatible with all Sigtronics intercom systems.

Circle (357) on Fast Fact Card

Mobile EMS encoder includes memory dial feature

The model 1012T microprocessor-controlled encoder is used in mobile emergency medical services (EMS) applications to selectively call different hospitals in accordance with the nationwide H.E.A.R. system. The unit from **Pyramid Communications** sends dialed strings of as many as seven digits in length from 10 user-programmable memory locations or direct entry. Dialed digits appear on an LED display as they are sent. All operating parameters are front-panel programmable and stored in non-volatile E^2PROM: 2,805Hz/1,500Hz tone sets, dial speed (8/20dps) and PTT delay/trunking operation. The $4\frac{1}{4}$" × 5" × 1" unit weighs 14 ounces and is housed in a one-piece extruded aluminum case with a sealed membrane keypad.

Circle (358) on Fast Fact Card

Decoder handles CTCSS, DCS and DTMF formats

Connect Systems' model CD-2 communications decoder decodes and displays 104 DCS codes, 50 CTCSS codes and all 16 DTMF digits. The CD-2 can be used with service monitors or any scanner to decode communication codes. All decoded data are also available on the RS-232 serial port. Optional interface software allows viewing of decoded data on a PC to acquire time, date and hits per CTCSS or DCS code plus usage graphs. All programmed data from the TP-154 and TP-154 Plus tone panels can be downloaded and then displayed or printed.

Circle (359) on Fast Fact Card

Mobile system prepares graphical accident reports

PSI International and **Shapeware** have released the Mobile Accident Reporting System (MARS), an accident report-writing system for public safety. MARS incorporates true graphical user interface functions including special drawing tools based on Shapeware's Visio 3.0 product. MARS uses Microsoft's Windows for Pen Computing tools and handwriting recognition technology to simplify and speed the capture of accident information. Additionally, MARS captures GPS information and can include digital photographs from an accident scene to provide a complete report. Officers also can make freehand drawings or notes at the scene for later inclusion in a word processing environment provided with MARS.

Circle (360) on Fast Fact Card

Data station operates in-vehicle or as a portable

PacketCluster Systems' mobile data communications system is a briefcase-mounted station that allows users in the field to send real-time messages, access database information and create and upload reports. The station consists of a notebook computer, radio transceiver and RF modem housed in a high-impact plastic case. A rechargeable battery and built-in antenna allow the unit to be used without external connections. For in-vehicle use, the unit also can be plugged into a dashboard dc outlet and used with an external magnetic-mount antenna. An AVL module is also available to automatic transmit a location to a central dispatcher.

Circle (361) on Fast Fact Card

Right-angle antenna fits specialty wireless niche

The EXR-2400-TN right-angle antenna from **Centurion International** is designed for mobile equipment operating at 2.4GHz. The injection-molded, flexible antenna is a movable right angle, giving the user a rotating antenna, ideal for several wireless devices including mobile laptop computers. The antenna is available with a TNC connector.

Circle (362) on Fast Fact Card

Unit monitors alarms, messages to alpha pagers

Miracom Technologies' Printpage system hosts computer alarm messages and E-mail messaging to alphanumeric pagers. The system does not require new software, programming or a new PC and works in either the UNIX or DOS environments. Printpage installs between the serial ports of the user's computer and printer, "spying" on the passing print traffic. The interface baud rate is selectable from 300bps to 9,600bps. The unit comes equipped with a 4-hour internal backup battery.

Circle (363) on Fast Fact Card

Power amplifier line expands to include 800/900MHz

LH Power Amplifiers has added three 800/900MHz amplifiers to its existing line of UHF amplifiers. Power levels are from 40W to 175W of clean power, and the amplifiers are rated for continuous duty to meet the demands of paging and communications operations. Teflon-filled, hardline coax is used in all RF circuits. The two largest amplifiers are constructed on a 6-pound, nearly 1-foot-square heat sink, cooled by three quiet fans and monitored for overtemperature, overdrive/underdrive and VSWR. The amplifiers endure an extended burn-in period at the factory and are backed by a two-year warranty.

Circle (364) on Fast Fact Card

Books give overview of private LMR, private microwave radio services

Two books published by the **Industrial Telecommunications Association (ITA)** and written by Frederick J. Day explore the origins of the private radio services and detail critical stages in their evolution.

Policies and Practices in the Regulation of Private Radio Communications Systems explores the history of private radio, from traditional two-way radio and one-way paging systems to 800/900MHz industrial, business and land transportation systems. It also examines the events and decisions that were critical in shaping the private operational-fixed microwave radio services.

Private Land Mobile Radio and Private Microwave Radio Decisions: A Chronology and Summary presents a look at more than 1,000 FCC decisions affecting the private radio services, from 1934 to the present.

Circle (250) on Fast Fact Card

Catalog details towers

An eight-page catalog from **Sabre Communications** features the company's line of self-supporting and guyed towers, as well as custom-built towers for AM, FM, microwave, cellular, CATV and other applications. The publication also reviews Sabre's in-house design, manufacturing and installation capabilities.

Circle (251) on Fast Fact Card

Catalog highlights new products

A 38-page catalog highlights products added to **Zetron's** 1995 guide with a short description and a page number telling where to find more detailed information. The guide includes more than 100 products and services, ranging from microphones to wide-area voice and data communications systems.

Circle (252) on Fast Fact Card

Data sheet covers modulation meter

A two-page data sheet lists the specifications and enhancements of the model 8211 FM/AM modulation meter. It explains why the 8211 provides high-performance and self-calibration capability, and explains the advantages of true peak detection. The data sheet from **Boonton Electronics** details why the 8211 is suited for maintenance of mobile communications equipment.

Circle (253) on Fast Fact Card

Catalog includes components

A 44-page wireless catalog from **Loral Microwave-Narda** covers components, networks and instruments for SMR, cellular and personal communications services (PCS) applications. The catalog features advanced products such as receiver multicouplers, high-power hybrid combiners and the CellGuard power and VSWR monitor, which is available in a remote display version.

Circle (254) on Fast Fact Card

Short-form catalog lists test and measurement products

A 12-page, color, short-form catalog of the top-selling **Anritsu Wiltron** test and measurement products is available. Products are organized by application with a concise listing of specifications and features. The catalog provides an overview of the company's product line, including spectrum analyzers, digital mobile radio base station testers, network analyzers, bit error rate testers and data transmission analyzers.

Circle (255) on Fast Fact Card

Catalog includes wiring accessories, identification products

The 74-page Wiring Accessory Specialists Catalog from **Nelco Products** contains seven color-coded sections: cable ties and accessories; terminals and connectors; identification products; routing products including sleeving and tapes; tubings for a variety of purposes; related products and tools for assembly; and services such as cutting and hot stamping. The catalog provides product descriptions, specifications, part numbers and photographs or line drawings relating to each product.

Circle (256) on Fast Fact Card

Catalog contains electronic repair parts

A 324-page catalog contains more than 21,000 total items and 2,600 new ones, including project accessories, semiconductors, connectors, test equipment and computer products. **MCM Electronics'** catalog introduces Nady microphones, Perma-Seal heat sealable nylon splices and a new line of Eveready products.

Circle (257) on Fast Fact Card

MCI enters into agreements with PageNet, SkyTel

MCI, Washington, DC, has entered into agreements with Paging Network (PageNet), Plano, TX, and SkyTel, Washington, DC, to provide wireless messaging services nationwide to consumers and businesses under the MCI brand name.

MCI will provide local and nationwide messaging services to its Friends & Family customers as part of the company's Friends & Family Connections program. MCI customers will be able to receive text messages, electronic mail, fax and voice mail notification, and news and information updates through paging and portable computing devices.

Targeting the growing mobile work force, MCI will market paging and messaging services to businesses under the brand name networkMCI Paging.

Western Multiplex to merge with Glenayre

Glenayre Technologies, Charlotte, NC, and Western Multiplex, Belmont, CA, have signed an agreement to merge the two companies. The merger is intended to capitalize on Glenayre's worldwide distribution system and customer base.

Western Multiplex designs, manufactures and sells digital and analog point-to-point microwave radios for a variety of markets. The company will operate as a division of Glenayre, representing a new business segment that is complementary to Glenayre's core customers but also increases diversity of Glenayre's products and markets.

NNS, Incom to jointly operate 220MHz licenses

Incom Communications (ICC), Anaheim Hills, CA, and Narrowband Network Systems (NNS), Mountlake Terrace, WA, have reached an agreement in principle to operate their 220MHz licenses jointly. ICC will act as the system manager. The agreement is subject to final approval from each company's board of directors. The two companies have management agreements for a total of 137 220MHz licenses in 40 markets throughout the United States.

The complete buildout is on schedule to meet the FCC deadline. All of the infrastructure hardware is in-house or on order and is fully funded by ICC and NNS.

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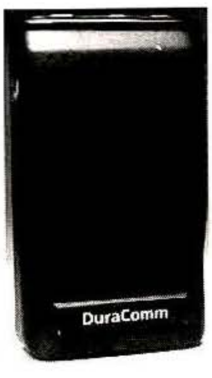

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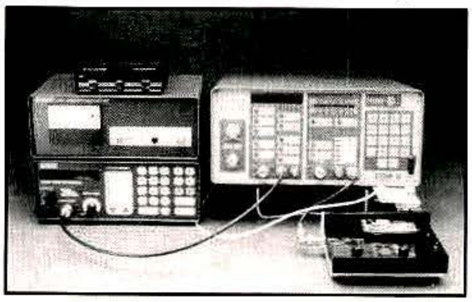

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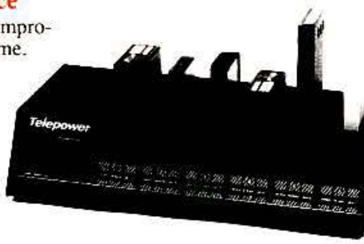

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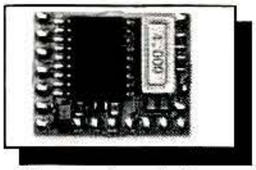

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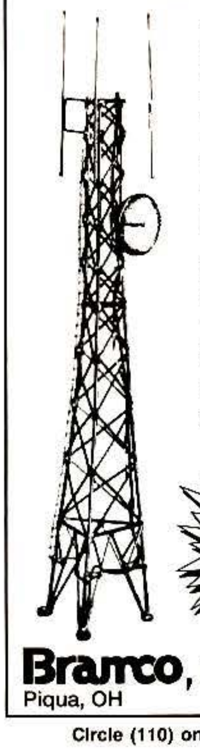

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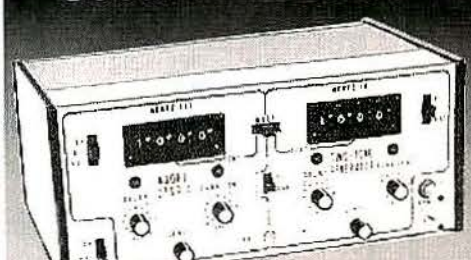

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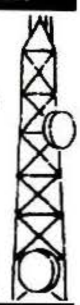

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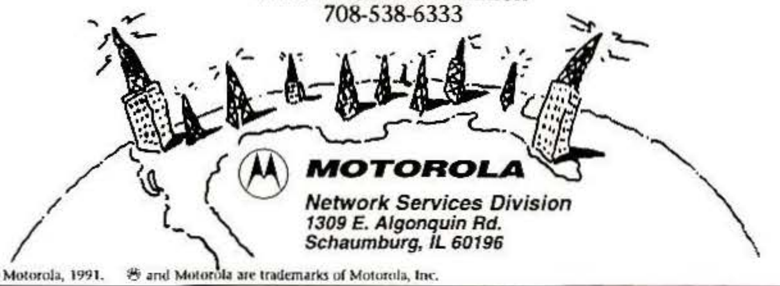

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Publications

A d index/hot line

Company	Page Number	Fast Fact Number	Advertiser Hotline
Advanced Receiver Research	64	62	203-582-9409
Allen Telecom Group	IFC	1	800-229-4706
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Argus Business	IBC	2	404-618-0499
Astron Corporation	31	28	714-458-7277
Automation & Electronics Engr.	82	92	800-527-4596
Avcom of Virginia	60	57	804-794-2500
Bomar	54	49	800-526-3935
Bramco, Inc.	87	110	513-773-6255
CELWAVE	18-19	17	800-321-4700
Channel Element Headquarters			800-237-9654
Chargeguard Corp.	87	109	800-458-3410
Cimarron Technologies	23	21	800-487-7184
David Clark Co., Inc.	14	13	508-751-5800
Combined Technologies, Inc	67	65	513-595-5900
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Communications Associates, Inc.	85	99	800-435-9313
Communications Data Services	92	117	800-441-0034
Communications Specialists	BC	3	800-854-0547
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Crystronics, Inc.	80	96	305-566-6949
Cushcraft/Signals Corp.	15	14	800-258-3860
Diablo Communications, Inc.	94	123	510-236-3700
D & L Communications, Inc.	86,88	106,111	800-336-6825
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Eagle Telecom Intl.	30	27	713-280-0488
EDX Engineering, Inc.	91	115	503-345-0019
Electrocom	68	66	310-946-9493
El Paso Communications	89	113	915-533-5119
Ericsson	35	32	800-GE1-2345
E Trunk Systems, Inc.	86	104	914-245-1128
Fourth Dimension	81	88	516-467-1220
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IFR Systems, Inc.	39	35	316-522-4981
JBRO Batteries, Inc.	29	26	800-323-3779
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Mechem Electronics	84	98	703-891-0569
Metroplex Mobile Data	70	70	305-739-0850

Company	Page Number	Fast Fact Number	Advertiser Hotline
Midian Electronics, Inc.	27	24	602-884-7981
Modular Communication Systems	48	43	818-764-1333
Motorola C&E	95	124	708-538-6333
Motorola GPID	13	12	800-520-7243
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NEC America Inc.	41	37	214-751-7273
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Norton Engineering	90	127	703-938-5745
Pekaar Communication, Inc.	85	100	201-772-0704
Photocomm, Inc.	66	76	800-223-9580
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TX RX Systems, Inc.	20	18	716-549-4700
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Versatel Communications	85	101	800-456-5548
Vocom/RF Corporation	22	20	800-USA-MADE
Wacom Products, Inc.	16	15	817-848-4435
WAVETEK GMBH	34	31	
West Coast Radio	83	96	310-268-2464
Western Multiplex Corp.	53	48	415-592-8832
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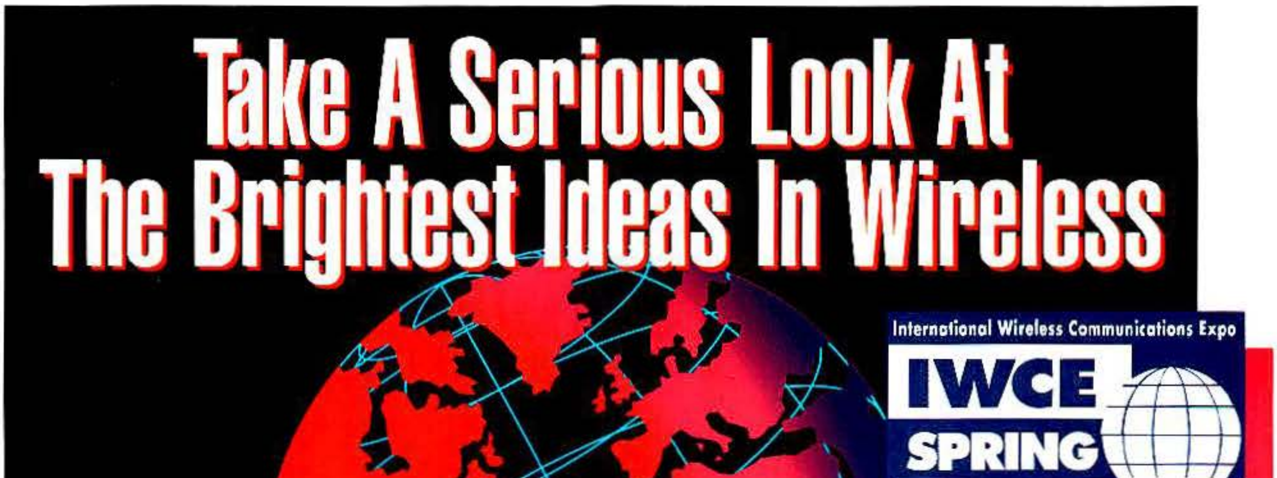
Zetron, Inc.	38,55	34,50	206-820-6363



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